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Infrared wireless communication

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Masters Project

Infrared Wireless Communication

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Certificate of Approval

Masters' Project

This is to certify that the Masters' Project of

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With a major in Computer Science
has been approved by the Project Committee as satisfactory
for the project requirement for the Master of Science degree

Thesis Committee:

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Revision Record

Version #	Date	Changes/Updates/Additions/Modifications
1.0	Sept. 11, 1995	First draft version
2.0	Sept. 29, 1995	Completed section 6 (IrDA SIR Physical Layer Link Modified and updated Section 2 and 3 Added the List of Figures
3.0	Oct. 9, 1995	Incorporated the suggestions from project advisor A'isha Ajayi in section 1, 2, 3 and 5. Renumbered the sections - Introduction is section 1 whereas it was 2 in version 2.0 Updated section 6 (IrDA Infrared Link Access Protocol (IrLAP)). Added section 5.1 and updated sections 5.2 and 5.3
4.0	Nov. 5, 1995	Added section 7 explaining the IrDA link management protocol (IrLMP)
5.0	Nov. 26, 1995	Added section 9 describing the IrCOMM protocol and the how it changes the existing printing model to accommodate Infrared based printing. Section 10 examines the IrDA compatible products in the market
6.0	Jan. 18, 1996	Completed the section 8 on Infrared transport protocol. Added section 10 explaining Plug and Play extension to the link management protocol. Renumbered section 10 and 11 to 11 and 12.
7.0	Feb. 4, 1996	Added section 12 explaining Infrared wireless communication and its competition
8.0	Feb. 11, 1996	Incorporated suggestions from project advisor A'isha Ajayi making adding more info, correcting typos and condensing fragmented sections. Updated the entire Reference section. Added the section 13 which includes the list of acronyms. Renumbered section 13 of references to section 14.
9.0	Feb. 18, 1996	Added the conclusion (section 13) and renumbered section 13 and 14 to sections 14 and 15.

10.0	March 1, 1996	Shortened the abstract and moved rest to the Introduction section. Added the working of the IrLAP link to the section 6.5 (IrLAP operating procedure). Corrected some typos and grammatical mistakes.

Abstract

Infrared wireless communication has already proven to be commercial success in the Television (TV) and Video Cassette Recorder (VCR) remote markets and is poised to become a key technology in a number of business markets. Over the next few years, we may witness an explosive growth of Infrared based "walk-up" data access and seamless indoor mobile data networking. The protocol architecture proposed by Infrared Data Association (IrDA), a non-profit organization founded in the summer of 1993, is very rapidly emerging as an industry wide infrared standard for "walk-up", point-to-point communication. The paper examines the IrDA protocol model and how the current printing model can be modified to work over the IrDA proposed protocol stack.

1. Introduction

Wireless communication is the process of communicating information over a distance through free-space instead of using a wire or other physical medium. This can cover many diverse technologies. Modulated radio wave frequencies are used to broadcast signals such as for television or radio. It can likewise mean radiated transmissions between and among antennas for two-way or limited-party interactive communications. Or it can mean the use of sound waves such as sonar, infrared signals for hand-held television remote controls or even modulated laser signals for intersatellite relays in space. [1] Throughout the world, the movement towards wireless communication seems irreversible. Wireless communication represents personal communications of the 90's. Wireless solutions provide logical presence through physical mobility. You can stay in touch wherever you are, whenever you want.

The major distinguishing feature of wireless telecommunications as opposed to wire communications is that the signal is radiated into free-space rather than confined to a wire, such as a coaxial cable or a fiber optic link. [1] This feature has several inherent advantages. Anyone can receive the signal in the broadcast area irrespective of whether they are at a fixed or mobile. New links can be established at a short notice and minimal cost overhead as no physical links have to be installed. . You can stay in touch whenever you want, wherever you are. The disadvantage is that the wireless signals are spread in free-space which posses severe limits on privacy of communications. Wired communication thus restricts signals while wireless does not. It is for this very reason wireless signals should be low in power so that they can be confined to small zones. This way the use of the assigned frequency is geographically limited to a small zone and the same frequency can be reused in other zones. This in turn effectively boosts the capacity and effective bandwidth of wireless systems. Reuse of frequency is critical to the growth and development of the wireless communication in the twenty-first century.

Starting with a broad overview of the breadth of wireless communication, the paper presents the key reasons why Wireless Communication is becoming increasingly popular in the business world. The paper then briefly looks at some of the emerging and promising

technologies both in the Wireless Local Area Networks (LAN's) and Wireless Wide Area Networks (WAN's).

The majority of the paper focuses on the protocol architecture proposed by Infrared Data Association (IrDA). The protocol architecture of IrDA has three mandatory compliance levels and the paper examines the design specifications of these mandatory levels. These levels are:

- Serial Infrared (SIR) Physical Layer Protocol
- Infrared Link Access Protocol (IrLAP)
- Infrared Link Management Protocol (IrLMP)

Besides the mandatory compliance levels IrDA standard provides non-mandatory solution for

- Infrared Transport Protocol (IrTP) and Tiny Transport Protocol (Tiny TP)
- IrCOMM (the emulation of serial and parallel ports over the IrLAP and IrLMP)
- Plug and Play (PnP)

These solutions have also been explored and presented in the paper.

An overview of some existing products with infrared features based on the IrDA functionality has been provided. Finally a comprehensive critique on the complete IrDA protocol architecture / model highlighting its strengths and weaknesses as compared with the RF communication. The paper concludes with a subjective assessment of the future of the infrared technology.

2. Why go wireless ?

Over the last decade companies such as Boeing, IBM, Kodak, Xerox have downsized and re-engineered their workforce in order to be cost efficient, productive and better serve their customers needs. One of the major trends has been to move workforce out of their offices closer to the customers, where they can spend more time understanding their problems and providing solutions. Approximately 48 million Americans alone have jobs requiring them to be "mobile" much of the time. This has led to radical changes in the ways many of us work, and has created numerous challenges for managing a mobile work force and keeping it productive. To realize the expected efficiency gains, a mobile workforce requires reliable, easy-to-use and low-cost way to access information from any location. For many, wireless communication best satisfies all of these needs.

- **Mobile workforce:** Leaving behind the wired phones and computers can decrease the productivity of the mobile workers. But wireless communication provides a preferred solution to the mobile workforce to access information while being away from the office and stay connected with changes. This restores productivity, creating a "virtual" office.

- **Increased Customer Satisfaction:** Quick response time and the ability to spend more time with customers using wireless communication helps increase customer satisfaction.
- **Reduced cost:** Each year, about half of all the companies relocate at least part of their operations. It can cost as much as $2,000 to move an employee's workstation which includes the cost of moving, wiring and installation. A wireless terminal costs less than $500 for a comparable move.[2] Beside the cost to maintain a wireless network are significantly less than the wired network.
- **Connectivity where previously not feasible:** The bulk of the wireless systems are being installed in place of direct-cabled networks because the location of the computing devices (nodes) makes running wire from the node to the network expensive or technically impossible. The following situations fall into this category:
    - Older buildings with stone or asbestos are difficult to wire
    - Add coverage to common areas (like conference rooms) where groups will be gathering and where Local Area Network (LAN) connectivity is important
    - Leased / temporary offices do not justify the exorbitant cost of installing the wired network
    - Over wired - cable trays and conduits are filled to capacity
- **Improved user productivity:** Provides users with the ability to view e-mail, call a customer, check inventory from wherever they are. This remote access of information provides quick response time and increases productivity.
- **Extension of wired LAN Connectivity:** Wireless are also being installed along with the existing wired systems due to the following reasons:
    - As backup for emergency or disaster recovery situations
    - Easy testing of the equipment before installing a wired network
    - Complement to wired LAN's and applications

3. Types of wireless solutions

There are two basic type of wireless solutions:

- Wireless local area networks (LANs):
- Wireless wide area networks (WANs):

3.1. Wireless local area networks (LAN's)

Wireless LANs enable communication between shorter distances e.g. one building or a college campus. They are self sufficient and do not require additional services in order to operate. Wireless LANs can transmit at a distance of hundreds to thousands of feet at

speeds of the order of Mbytes / sec. Generally, the shorter the distance (range)between the nodes, the higher the performance (speed).

Several different types of infrared and RF systems can be used for a wireless LAN extensions. The choice of the system is normally based on the following criteria:

- Physical location of the system
- Distance between the wireless node and the closest network point
- The structural composition of the building in which the system will be located e.g. steel, concrete, metal, plastic etc.
- Type of data that will be exchanged between the nodes and the network
- Other issues include security, network management, performance and protection from interference

3.1.1. Wireless LAN topologies

There are two types of wireless LAN topologies / configurations

- **Peer-to-peer topology:** This topology enables the direct communication from one device to another, without the need for going through an intermediate device. Peer-to-peer communications is especially well suited for adhoc or temporary networking in cases where the employees move frequently or the business is housed in a building with a short-term leases. This topology is suitable for small, collaborative teams working in closely located offices. Installing such small networks is fairly easy and fast. Security and network management issues are not resolved with this type LAN. Peer-to-peer LANs offer a limited range of communications and coverage. However, the range can be increased by using an access point product to attach the wireless LAN to a wired LAN. The wired LAN then serves as a "backbone" link to other access points and wireless peer-to-peer LANs. If you require a LAN with basic functionality in an enclosed room, an infrared LAN with peer-to-peer functionality would most likely be the best choice.

Peer-to-peer Topology

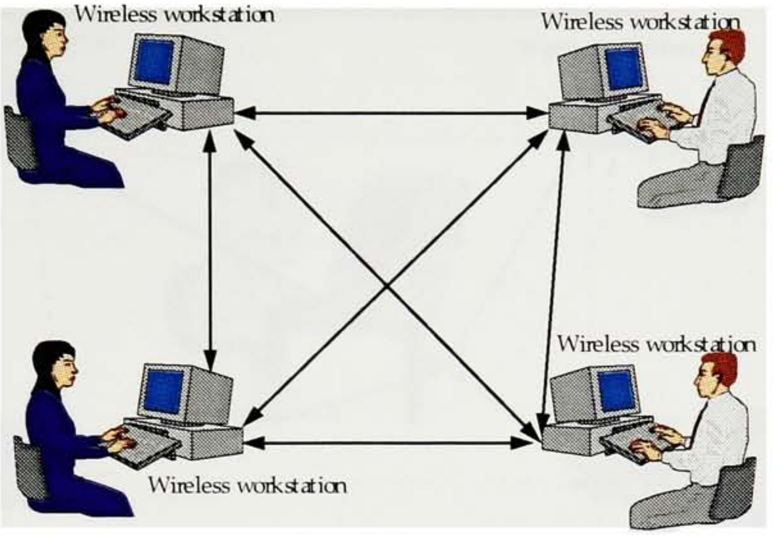


Figure 1. Peer-to-peer LAN topology

- **Base-to-remote topology**: Another wireless LAN topology employs base-to-remote communications. These networks use wireless LAN communications to link workstations (remote) to a central workstations (base), which is at the center of the wireless LAN. This topology works well for commercial use and can be stand alone LAN or wired LAN extension. Base-to-remote LANs provides greater coverage and range. The base unit can provide more security to LAN access and more effective management of the wireless LAN. If you need centrally controlled wireless LANs then a spread radio frequency LAN with base-to-remote topology could be a good choice.

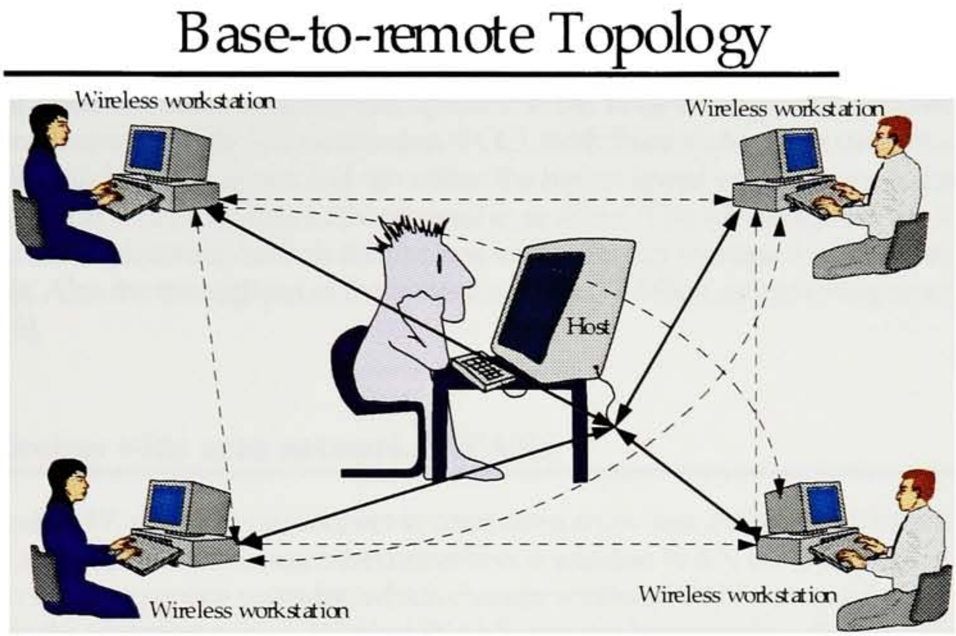


Figure 2. Base-to-remote LAN topology

3.1.2. Wireless LAN technologies

The two choices are:

Infrared: Infrared (IR) systems use a part of the electromagnetic spectrum just below visible light as a transmission medium. IR technology is well suited to very high data rates (~100 Mbits / sec).

Radio Frequency: Radio Frequency (RF) is the part of the electromagnetic spectrum where electronic signals travel as radio waves. Within these frequencies communications can be achieved over a wide range from the low frequency band to the extremely high frequency band [1].

In order to implement RF links **two** methods can be used:

- **Narrowband modulation technique** (NMT)
- **Spread-spectrum technique** (SST)

NMT have problems with multipath transmission and they are very sensitive to interference, so SST is preferred. Among SST's the most promising is code division multiple access (CDMA). In this case, a single code is assigned to an emitter inside a cell; if the emitter moves to another cell, a new code is given to continue transmission.

There **two main choices** for RF wireless links that can be used for a point-to-point type of LAN. These are:

The **first** one is the unlicensed RF solution offered by NCR, O'Neill and Proxim. This solution uses SST in the unlicensed frequency band of 902-928 MHz. There are concerns about the long term viability of the 902-928 MHz unlicensed band because in addition to unlicensed use, it is also available to four different groups of licensed users. This means that the unlicensed users must accept any and all interference generated by any of the licensed users and must not interfere with them.

Motorola offers the **other** solution that operates in the 18 GHz range and is licensed by the Federal Communications Commission (FCC). With these systems the users don't have to gamble with RF interference and can utilize the higher speed wireless connection. Motorola offers an RF wireless LAN referred to as Altair. The advantages of the Altair system are that Motorola controls the licenses and can better manage the interference potentials. Also the throughput of the system is about 5.7 Mbps, approaching true LAN speeds [6].

3.2. Wireless wide area networks (WANs)

With wireless WAN's you can connect to computers anywhere in the world, provided access is allowed. In most cases, interconnection a wireless WAN is accomplished with a wireless carrier or service provider, which charges wireless WAN's users a fee for providing the transport service. Wireless WAN's provide transmission distance of many miles, but at generally lower data rates.

3.2.1. Wireless WAN technologies

There are two basic types of wireless service networks available in the wide area environment.

- **Voice service networks [3]**: Although these networks are used primarily for voice, data can be accommodated.
    - *Specialized mobile radio (SMR)* is a two-way radio system operated by a commercial service, which owns and maintains the base station and holds the necessary radio licenses. You can easily subscribe to an SMR system.
    - *Cellular* telephone systems use radio signals to connect mobile users to the land-line telephone network. Cellular networks can be used for voice, data and fax transmissions. Subscribers to a cellular network are charged based on the amount of time that they are connected to the network. Therefore, cellular is well suited for large messages, such as faxes, rather than short ones.
    - *Personal communication services (PCS)* is a digital service that will enable users to make calls from lightweight, portable handsets to send data by using small wireless computers. PCS may encompass a broad range of services, such as advanced paging and wireless e-mail, in additional to voice.

- **Data service networks [3]:** These networks include traditional radio-paging networks and networks that use packet-radio technology.

  - *Radio Paging* was originally established as non-speech, one-way, personal selective calling with alert, without message, or with defined messages. Current paging systems may include limited capabilities for two-way communication and delivery of short voice messages.

  - *Packet radio networks* support two-way exchanges of short messages and are well suited for field-service solutions. Information is transmitted in groups of data called packets. Subscribers are charged on the number of packets transmitted.

  - *Advanced radio data information service service (ARDIS)* is a nationwide (USA and Canada) packet-radio network that provides two-way, interactive, real-time data communications. ARDIS also provides deep in-building coverage from coast to coast, In 1993, ARDIS announced support for automatic nationwide roaming, which supports wireless users when moving from one city to another, and ARDISmail, which supports wireless modems and provides gateways to other mail systems.

  - *RAM Mobile Data* is a national, two-way packet radio network using the Mobitex architecture, which is managed by the Mobitex Operators Association. RAM Mobile Data provides host connectivity, connectivity to third-party information services, and broad e-mail connectivity. Registration is automatic and roaming is supported.

  - *Cellular digital packet data (CDPD)* is an overlay network providing packet data over an analog cellular voice infra-structure. Newly announced CDPD transmission products and services from the network providers will provide a more reliable, and potentially less expensive, solution than transmitting over a circuit cellular analog network. Furthermore, subscribers are expected to be charged for only the number of data packets transmitted.

4. Infrared wireless communication

Infrared can be thought of as electromagnetic energy masquarading as heat. [4] It has physical properties identical to that of the radio and light waves the main difference, however, is that infrared is an electromagnetic wave with an extremely short wavelength.[11] Infrared systems use a part of the electromagnetic spectrum just below visible light as a transmission medium.

Infrared systems are an ideal choice if

- The distance between the node and the rest of the network is less than 800 feet.

- The node is "line-of sight" to a network connecting point. Infrared being a light medium is limited to a straight or "line-of-sight" path (like the TV and VCR remote controller).
- If the data to be transmitted is not very large. The speed capabilities at present are limited to 242 KBps (kilobytes / second) which may not be satisfactory if a large amount of data and graphics need to be moved to this node.

4.1. Location of infrared waves in the electromagnetic spectrum

The electromagnetic spectrum extends in both directions from the visible region. The visible light spectrum ranges from the bright red color at one end to the violet at the other. Red light has the longest wavelength and the lowest frequency while violet light has the shortest wavelength and highest frequency. On one side of visible region are the shorter-wavelength, higher frequency light rays which include ultraviolet (UV), x-rays and cosmic rays. The other side of visible region are longer-wavelength, lower-frequency light rays which first includes infrared light and then, as wavelengths become longer, radio waves. [5]

Infrared has an extremely short wavelength. Infrared waves are invisible and are usually referred to as infrared light or IR in the communication world. The wavelength of IR is between 750 nm and 3000 nm but the IR of greatest interest for the communication is known as Near Infrared, so called because its range is below the visible spectrum, which sits between 380 nm and 750 nm.[4]

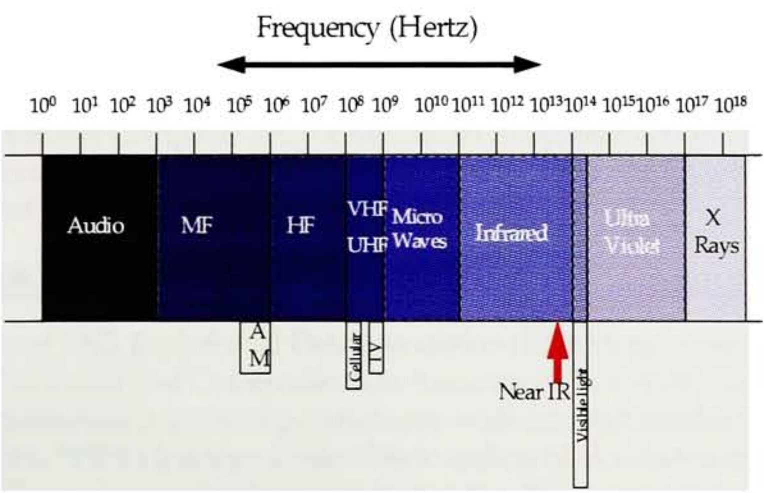


Figure 3. The electromagnetic spectrum

Infrared is not licensed anywhere in the world and therefore there is no spectrum

assignments to worry about. Unlike many other wireless devices there is a genuine possibility that the same Infrared device can be used anywhere in the world. Vendors will appreciate the ability to design and produce one model for distribution in multiple countries. [7]

4.2. Brief history

The sun is the largest generator of IR, UV and other type of radiation. Visible light has a long history as a means of wireless communication. From mirrors reflecting sunlight signals between mountains to the first transmission of human voice over a light beam in 1880 by Alexander Graham Bell, light beam communication has gradually shifted with improvements in technology from visible light to infrared.[4]

Most of the light communication until recently has been done using a focused beam or line-of-sight technique. This implied that the transmitting beam had to point, or focus directly on the receiver. But with the development of inexpensive wide area IR light detectors and light emitting diodes (LED), diffuse light communication has become possible.

Over the past few years, vendors have attempted to sell infrared data communications products in a variety of configurations. Photonics Corporation, one of the industry's pioneers, entered the market with a system which they hoped would replace office cabling by bouncing infrared beams off the ceiling. A company called UnTied Telecom developed a point-to-point infrared link for replacing fiber optic cable in token Ring networks. Both of these solutions from Photonics Corporation and UnTied Telecom targeted fixed location applications and met with limited success. [7] Currently, most of the infrared data products focus on portable applications. Spectrix Corporation has developed a system composed of infrared "access points" interconnected via an Ethernet LAN backbone that supports seamless roaming for users equipped with portable terminals. Photonics has introduced its Cooperative and Collaborative product families for creating spontaneous networks of Personal Computer (PC) or Macintosh compatible computers. One of their new products called Etherpoint also offers seamless roaming. IBM has licensed Photonics infrared technology and is introducing similar products. [7]

4.2.1. Infrared Data Association (IrDA):

In the summer of 1993, the Infrared Data Association (IrDA) was formed and aligned with the Portable Computer and Communication Association (PCCA).[6] The charter of this non-profit organization is to develop an industry-wide infrared standard for point-to-point communications. Within less than a year of its founding IrDA released its worldwide standard defining an interoperable, infrared serial data link that (initially) supported speed of 115.2 Kilobits per second (Kb / s) at a minimum distance of one meter.

IrDA started with a membership of dozens of firms such as Apple Computers, American Telephone and Telegraph (AT&T), Casio, Compaq Computers, Digital Equipment

Corporation (DEC), Fujitsu, General Magic, Hewlett-Packard (HP), International Business Machines (IBM), Intel, Matsushita, Microsoft, Motorola, Siemens, Sun Microsystems and Toshiba. Currently IrDA membership represents over 100 industry leaders in computer and telecommunication hardware, software, component sector and product testing. Working committees heavily use e-mail and file transfer protocol (FTP) on Internet. Over 500 individuals E-mail addresses are registered on the association's general communication reflector which provides a broadcast of participant comments / contributions and IrDA announcements to all members. Amongst all the members HP and IBM have been the most prominent contributors. HP's proposal for the Serial Infrared (SIR) was adopted over competing submissions from Sharp and General Magic[7]. Work is currently going on between IBM, Sharp and HP to devise the standard for operation at 4 Mbps (backward compatible to the 9600 - 115 Kbps speeds). The 115.2 Kb / s speed is sufficient for transferring small data, but higher speed (4 Mb / s) is necessary for transferring larger data.

With major national and international mobile computer systems providers to embed full IrDA functionality in most future products models; cross platform communication between devices should be possible. Applications will exchange data between different brands of computers and other devices like notebook PC's, printers, fax machines, network nodes, data modems, telephones, automated tellers, personal digital assistants (PDA's), electronic organizers and other portable devices.

4.3. IrDA protocol model

The IrDA's wireless "point and beam" data transfer is simple yet compelling. It provides an interoperable, low cost, low power, half duplex serial data interconnection standard that supports a walk-up, point-to-point user model that is adaptable to a wide range of appliances and devices.[8] IrDA is working hard to realize the ultimate goal - "if it works over a wire / cable it will work over the IrDA infrared data link".[9]

The IrDA model has three mandatory compliance levels. Besides the mandatory compliance levels IrDA provides non-mandatory solutions / levels. The mandatory layers correspond to the open system interconnection (OSI) reference model and were derived from an existing industry standard communication protocols like the High level Data Link Control (HDLC). Each layer provides a different level of abstraction and performs well define functions. The three mandatory compliance levels are:

- Serial infrared (SIR) physical layer protocol [10] (Refer to section 5.0 for details)
- Infrared link access protocol (IrLAP) [11] (Refer to section 6.0 for details)
- Infrared link management protocol (IrLMP) [12] (Refer to section 7.0 for details)

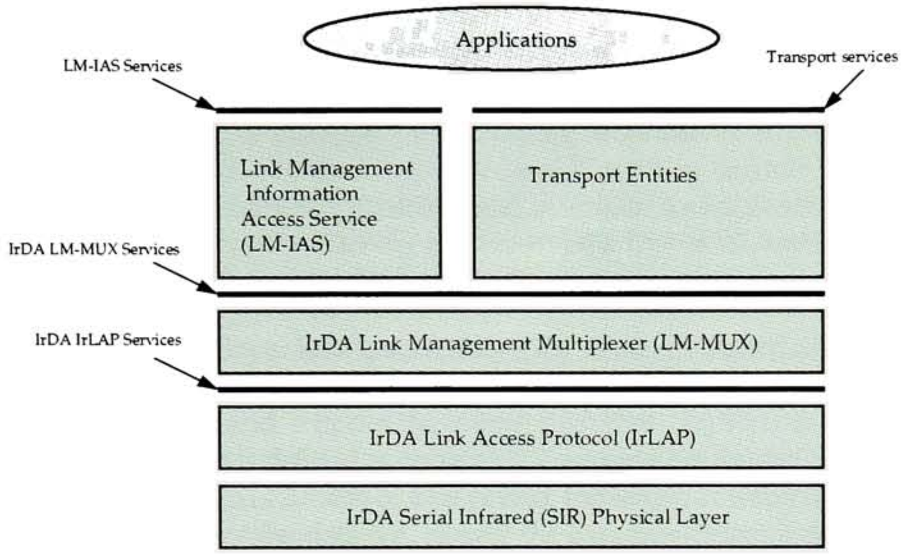


Figure 4. IrDA protocol architecture

Besides the mandatory compliance levels IrDA model provides non-mandatory solution for:

- Infrared transport protocol (IrTP) [13] (Refer to section 8.0 for details)
- Tiny transport protocol (Tiny TP)
- IrCOMM (the emulation of serial and parallel ports over the IrLAP and IrLMP) [14]
- Plug and play (PnP) [15]

5. IrDA serial infrared (SIR) physical layer link [10]

The physical specification is intended to facilitate the point-to-point communication between electronic devices (e.g., computers and peripherals) using directed half duplex serial infrared communications links through free space. It consists of an encoder / decoder (which performs the IR transmit encoder and IR receiver decoder) and the IR transducer (which consists of the output driver and IR emitter for transmitting and receiving / detecting). The encoder / decoder interfaces to the Universal Asynchronous Receive / Transmit (UART) is expected to be already present in most computers.

The IrDA-SIR physical layer link specification [10] takes a standard asynchronous serial character stream from the UART (where a frame is defined as a start bit, 8 data bits, no parity bit and a stop bit) and encodes the output such that 0 represents a pulse and 1 represents no pulse. A pulse is defined as occupying a nominal minimum of 1.6 microseconds to a maximum of 3 / 16th of a bit period, the length of which is inversely proportional to the bit rate of the data (i.e., slower the data rate longer is the pulse). This pulse stream forms the input to the driver for the Infrared (IR) emitter that converts the electrical pulses to IR energy.

This section specifies the optical media interfaces and 1.152 Mb / s and 4.0 Mb / s modulation and demodulation. It provides the specification for the active input interface and active output interface and the overall link. Optical interface specifications are independent of technology and apply over the entire life of the link and are readily testable for conformance.

5.1. Serial infrared (SIR) physical layer features

5.1.1. Point-to-point overview

The serial infrared link supports optical link length from zero to at least 1 meter for accurate (bit error rate of 1 in 10^9 or better) in free space communication between two independent nodes.

5.1.2. Environment

There are four ambient interference conditions in which the receiver is to operate correctly. Each condition is to be applied separately.

- Electromagnetic fields of 3V / m maximum
- Sunlight of 10 kilolux maximum at the optical port
- Incandescent lighting of 1000 lux maximum
- Fluorescent lighting of 1000 lux maximum

5.2. Media interface description

5.2.1. Physical representation

A block diagram of the serial infrared link is shown in the Figure 4. The electrical signals to the left of the encoder / decoder at section "***A***" are serial bit streams in Figure 4. For data rates up to and including 1.152 Mb / s, the optical signals at section "***C***" are bit streams with a "0" being a pulse and a "1" being a bit period with no pulse. For 4.0 Mb / s a 4 PPM encoding scheme is used, with a "1" being a pulse and a "0" being the chip with no pulse. The electrical signals at section "B" are the electrical analogs of the optical signals at section "C". For data rates up to and including 115.2 Kb / s, in addition to encoding, the signal at section "***B***" is organized into frames with a start bit, 8 data bits and a stop bit. For data rate above 115.2 Kb / s, data is sent in synchronous frames consisting of many data bytes.

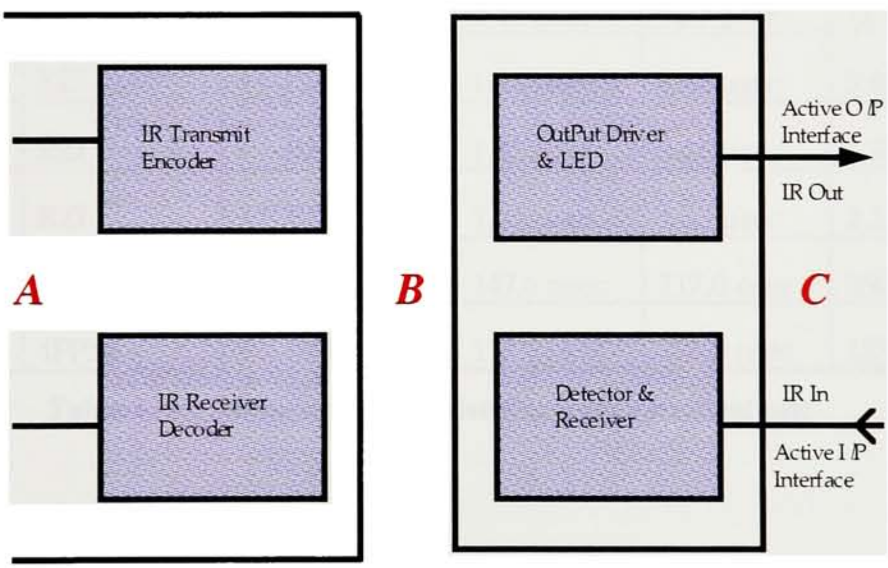


Figure 5. IR transducer module interfaces

5.3. Media interface specifications

5.3.1. Overall link

The link length is from zero to at least 1 meter. The distance is measured between the optical reference surfaces. The link shall operate and meet the bit error rate of 1 in 10^9 or better. An IrDA serial infrared interface must operate at 9.6 Kb / sec. Additional allowable rates listed below are optional. Signaling rate and pulse duration specifications are shown in Table 1.

Signaling Rate (kb/s)	Modulation	Rate of tolerance % of Rate	Pulse Duration Minimum	Pulse Duration Nominal	Pulse Duration Maximum
2.4 Kb / s	RZI	+/-0.87	1.41 μsec	78.13 μsec	88.55 μsec
9.6 Kb / s	RZI	+/-0.87	1.41 μsec	19.53 μsec	22.13 μsec
19.2 Kb / s	RZI	+/-0.87	1.41 μsec	9.77 μsec	11.07 μsec
38.4 Kb / s	RZI	+/-0.87	1.41 μsec	4.88 μsec	5.96 μsec
57.6 Kb / s	RZI	+/-0.87	1.41 μsec	3.26 μsec	4.34 μsec
115.2 Kb / s	RZI	+/-0.87	1.41 μsec	1.63 μsec	2.23 μsec
1.152 Mb / s	RZI	+/-0.01	147.6 nsec	217.0 nsec	260.4 nsec
4.0 Mb / s	4PPM	+/-0.01	115.0 nsec	125.0 nsec	135.0 nsec

Table 1. Signaling rate and pulse duration specifications

For signaling rates <= 115.2 Kb/s

- Pulse duration nominal = 3 / 16 of bit duration
- Pulse duration maximum = Pulse duration nominal + (greater of 2.5% of bit duration and 0.6)
- Pulse duration minimum = Pulse duration nominal for 115.2 Kb / s signal * Rate of tolerance

Example of calculating the Pulse duration for 2.4 Kb / s signaling rate

Pulse duration nominal = $3 / 16 * 1 / 2.4*10^3$ = 78.125 sec ≅ 78.13 μsec

Pulse duration maximum = 78.13 + (greater of $2.5 / 100 * 1 / 2.4*10^3$ or 0.6)

= 78.13 + (greater of 10.41 or 0.6)

= 78.13 + 10.41 = 88.54 μsec

Pulse duration minimum = 3 / 16 * 115.2 * 0.87

= 1.63 * 0.87 = 1.41 μsec

Example of calculating the Pulse duration for 115.2 Kb / s signaling rate

Pulse duration nominal = $3 / 16 * 1 / 115.2*10^3$

= 1627 * 10-6 ≅ 1.63 μsec

Pulse duration maximum = 1.63 + (greater of $2.5 / 100 * 1 / 115.2*10^3$ or 0.6)

= 1.63 + (greater of 0.21 or 0.6)

= 1.63 + 0.6 = 2.23 μsec

Pulse duration minimum = 3 / 16 * 115.2 * 0.87

= 1.63 * 0.87 = 1.41μsec

For signaling rates of 1.152 Mb/s

- Pulse duration nominal = 25% of bit duration
- Pulse duration maximum = Pulse duration nominal + 8% of the bit duration
- Pulse duration minimum = Pulse duration nominal - 5% of the bit duration

Example of calculating the Pulse duration for 1.15 Mb / s signaling rate

Pulse duration nominal = 1 / 4 * 1 / 1.152*106 ≅ 217 nsec

Pulse duration maximum = $217 + (5 / 100 + 1 / 1.152*10^6)$

= 217 + 43.4 = 260.4 nsec

Pulse duration minimum = 217 - (8 / 100 * 1 / 1.152*106)

= 217 - 69.44 = 147 nsec

For signaling rates of 4.0 Mb/s

- Pulse duration nominal = 50% of bit duration
- Pulse duration maximum = Pulse duration nominal + 8% of the bit duration
- Pulse duration minimum = Pulse duration nominal - 8% of the bit duration

Example of calculating the Pulse duration for 4.0 Mb / s signaling rate

Pulse duration nominal = $1 / 2 * 1 / 4.0*10^6$ = 125 nsec

Pulse duration maximum = 125 + (8 / 100 * 1 / 4*106)

= 125 + 10 = 135 nsec

Pulse duration minimum = $125 + (8 / 100 * 1 / 4*10^6)$

125 -10 = 115 nsec

5.3.2. Active output interface

The purpose of the active output interface (AOI) is to emit an infrared signal. The specified AOI parameters are:

5.3.2.1. Peak wavelength

Wavelength at which the optical output source intensity is a maximum. The maximum and minimum values are 0.90 and 0.85 respectively. These values hold good for all data rates.

5.3.2.2. Maximum and minimum intensity in angular range

Maximum intensity in angular range is the power per unit solid angle and is the maximum allowable source intensity within the defined angular range. Similarly minimum intensity in angular range is the power per unit solid angle and is the minimum allowable source intensity within the defined angular range. Both are measured in milliwatt per steradian.

5.3.2.3. Half Angle

The half angle is measured in degrees is the half angle of the cone whose apex is at the center of the optical port and whole axis is normal to the surface of the port. The half angle value is determined by the minimum angle from the normal to the surface where the minimum intensity in angular range is encountered.

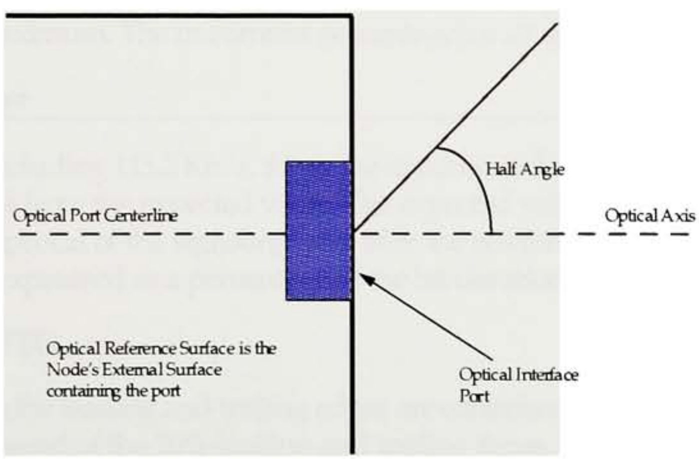


Figure 6. Optical port geometry

For convenience, the center of the optical port is taken as the reference point where the optical axis exits the port. The maximum and the minimum values of the Half-Angle is +/- 30 and +/-15 degrees.

5.3.2.4. Signaling rate

The signaling rate also known as the bit rate is the rate at which information is sent or received. It is usually measured in kilobits per second or megabits per second. Refer to Table 1 for signaling rate specifications.

5.3.2.5. Rise time Tr and Fall time Tf

Rise time (Tr) is the time intervals for the pulse to rise from 10% to 90% of the 100% value and the Fall time (Tf) is the time interval for the pulse to fall from 90% to 10% of the 100% value. The maximum Tr and Tf value for data rates of 115.2 Kb / s and below is 600 and the maximum Tr and Tf values for data rates above 115.2 Kb / s is 40.

5.3.2.6. Pulse duration

This is the duration of the optical pulse, measured between 50% amplitude points (relative to the 100% value, not the overshoot value), divided by the duration of the bit or symbol period (depending on the modulation scheme), expressed as a percentage. This parameter is used as a duty factor conversion between average and peak power measurements. Refer to Table 1. for the pulse duration values maximum, nominal and minimum for different data rates.

5.3.2.7. Optical over shoot

Optical over shoot (OOS) percentage of full (100%), is the peak optical signal level above the steady state maximum, less the steady state maximum, expressed as a percentage of the steady state maximum. The maximum percentage for all data rates should be 25%.

5.3.2.8 . Edge jitter

For rates up and including 115.2 Kb / s, this is the maximum deviation within a frame of an actual leading edge from the expected value. The expected value is an integer number of bit duration's (reciprocal of the signaling rate) after the reference or start pulse leading edge. The jitter is expressed as a percentage of the bit duration.

For 1.152 Mb / s , TBD.

For 4,0 Mb / s, both the leading and trailing edges are considered. From an eye diagram the edge jitter is the spread of the 50% leading and trailing times. The jitter is expressed as a percentage of the symbol duration.

5.3.3. Active input interface

The active input interface (AII) detects the optical signal that strikes it and conditions the receiver circuitry and then outputs it to the IR receive decoder. The specifications for the active input interface are:

5.3.3.1. Maximum irradiance in angular range

Maximum irradiance in angular range is the power per unit area (measured in milliwatts per square centimeter). The optical power delivered to the detector by a source operating at the maximum Intensity in Angular Range at minimum link length must not cause receiver overdrive distortion and possible related link errors. If placed at the Active Output Interface reference plane of the transmitter, the receiver must meet its bit error ratio (BER) specification. The maximum Irradiance in Angular Range for all data rates is 500 mW/cm^2.

5.3.3.2. Minimum irradiance in angular range

Minimum irradiance in angular range is the power per unit area (measured in milliwatt or microwatt per square centimeter). The receiver must meet the BER specification while operating at the Minimum Intensity in Angular Range into the minimum Half-Angle at the maximum link length. Minimum Irradiance in Angular Range for data rates of 115.2 Kb / s and below is 4.0 $\mu W/cm^2$ and for data rates of 115.2 Kb / s are 10.0 $\mu W/cm^2$.

5.3.3.3. Half angle

The half angle is measured in degrees and is the half angle of the cone whose apex is at the center of the optical port and whose axis is normal to the surface of the port. The receiver must operate at the minimum Irradiance in Angular Range from 0 angular degrees (normal to the optical port) to at least the minimum angular range value. There is no half angle maximum value for the active input interface. The link must operate at angles from 0 to at least 15 degrees.

5.3.3.4. Receiver latency allowance

Receiver latency allowance is measured in milliseconds or microseconds and is the maximum time after a node ceases transmitting before the node's receiver recovers its specified sensitivity. The maximum receiver latency allowance for all data rates is 10 msec.

5.4. 1.152 Mb/s modulation and demodulation

This section of the IrDA SIR physical layer link describes the modulation and demodulation at 1.152 Mb / s data rates. The reason this data rate has been chosen to explain the concept is because the encoding scheme used by 1.152 Mb / s is similar to 115.2 Kb / s. Both use similar packet format, data encoding, cyclic redundancy check (CRC), and frame format which are based on the optical interface specification.

5.4.1. Serial infrared interaction pulses

To guarantee compatibility with slower data rates (115.2 Kb / s and below) systems, once a connection of speed higher that 115.2 Kb / s is established, the system must emit a Serial Infrared Interaction Pulse (SIP) at least once every 500 msec as long as the connection

lasts to quiet the slower systems that might interfere with the link. The pulse can be transmitted immediately after a packet has been transmitted. The pulse is shown in figure below.

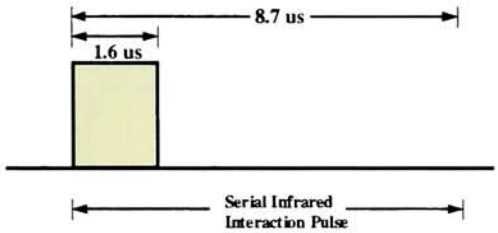


Figure 7. Serial interaction pulse (SIP)

5.4.2. Encoding scheme

The 1.152 Mb / s encoding scheme is similar to that of the lower rates except that it uses one quarter pulse duration of a bit cell instead of 3 / 16, and uses HDLC bit stuffing after five consecutive ones instead of byte insertion. The following illustrates the order of encoding.

Step 1 & 2: The raw transmitted data is scanned from the least significant to the most significant bit of each byte sent and a 16 bit Cyclic Redundancy Check (CRC)-Comité Consultatif International de Télégraphique et Téléphonique (CCIT) is computed for whole frame except flags and appended at the end of data. Both the address and control fields are considered as part of data

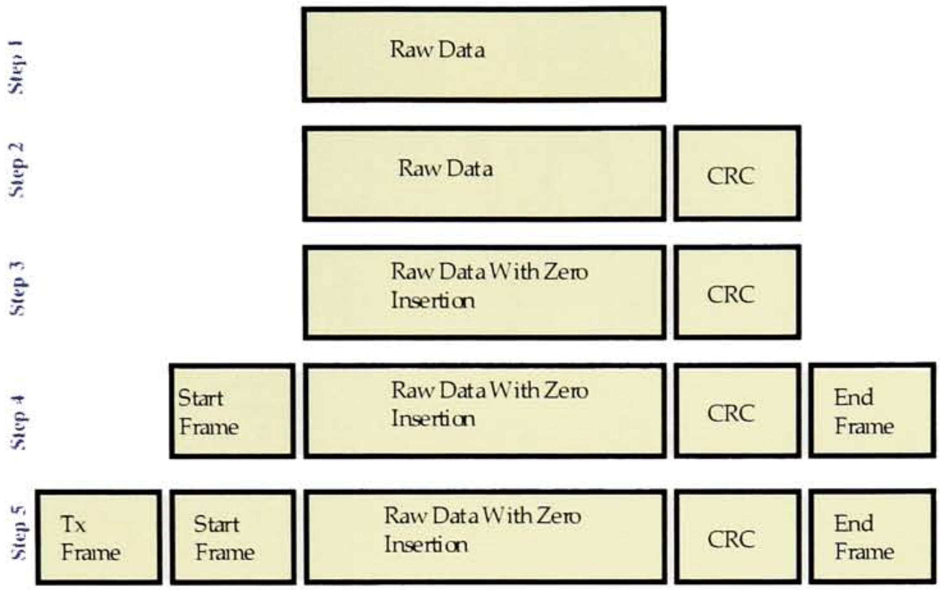


Figure 8. Encoding scheme for 1.152 Mb/s data rate

Step 3: A zero is inserted after five consecutive ones are transmitted in order to distinguish the flag from data. Zero insertion is done on every field except the flags.

Step 4: Beginning and ending flags are appended at the beginning and end. The flag used is '7E' hex.

Step 5: An additional beginning flag is added at the beginning. The flag used is '7E' hex. Refer to Figure 8. for encoding steps 1-5.

Step 6: The transmitter sends out 1 / 4 bit cell length of infrared signal whenever data is 0.

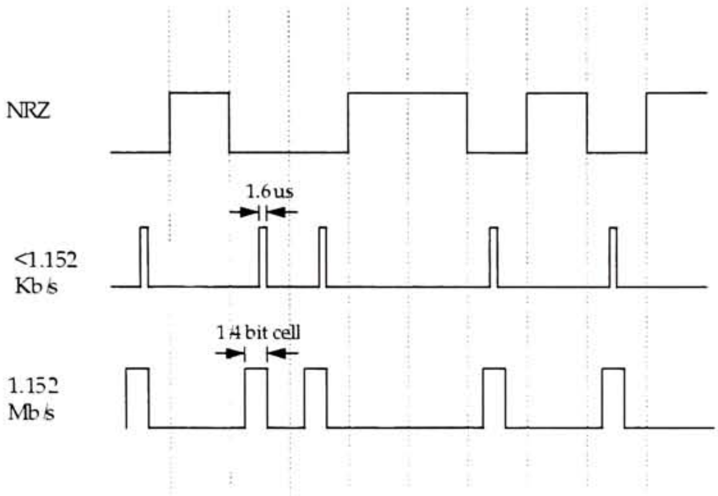
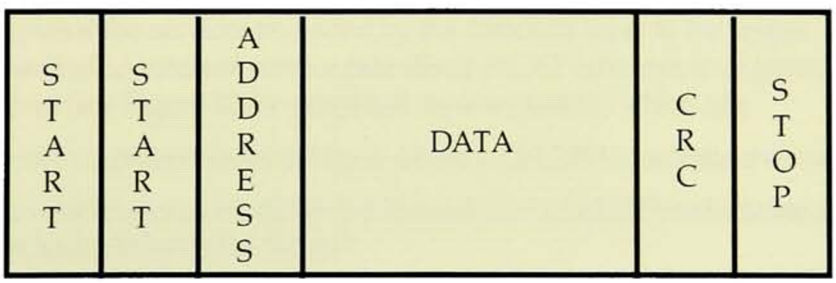


Figure 9. Encoded data transmission by the transmitter

5.4.3. Frame format

The 1.152 Mb / s frame format follows the standard HDLC format except that it requires two beginning flags, an address flag, a control flag, an information flag, a frame check sequence field and a minimum of one ending flag. '7E'hex is used for both the beginning and ending flags.



START	**- Start flag, '7E' hex**
ADDRESS	**- 8 bit address field**
DATA	**- 8 bit control field + upto 2K-3 bytes**
CRC	**- CCIT 16 bit Cyclic Redundancy Check**
STOP	**- Ending flag, '7E' hex**

Figure 10. Frame format

6. IrDA infrared link access protocol (IrLAP) [11]

The infrared link access protocol (IrLAP) of the IrDA standard describes the functions, features, protocol and services for interconnection between computers at the data link layer (equivalent to the layer # 2 in the OSI model). The data link layer protocol is generally referred to as IrLAP [11] and is derived from an existing asynchronous data communications standard (an adaptation of HDLC). IrLAP constitutes one layer in a hierarchical stack of communication protocol layers, it uses services provided by the physical layer and provides services to the layer above it.

The *main services* provided by the IrLAP are:

- Set dynamic 32 bit physical addresses
- Encapsulate all communications in frames with 16 bit frame check sequence (FCS) thus maintaining data transparency
- Discover devices within IR space
- Negotiate parameters for connections
- Setup connections
- Transfer data - which includes managing windows for reliable data transfer and retranslating on errors
- Reestablish a broken connection
- Manage time outs
- Close connection (link shutdown)
- Manage media access and turn around rules

6.1. Data link layer service specifications

This section explains the services provided by the data link layer to the upper layer. The services are specified in terms of service primitives. IrLAP employs four generic types of service primitives (see Figure 10 for graphical representation) which are:

- **Request** which is passed from the layer above it (IrLMP) to invoke a service
- **Indication** which is from IrLAP to the layer above it (IrLMP) to indicate an event or to notify an action initiated by IrLAP
- **Response** which is passed from the from the layer above it (IrLMP) to acknowledge some procedure invoked by an indication primitive
- **Confirm** which is passed from IrLAP to the layer above it (IrLMP) to convey the results of the previous service request

IrLAP provides two general types of services:

- Connectionless Services
- Connection-Oriented Services

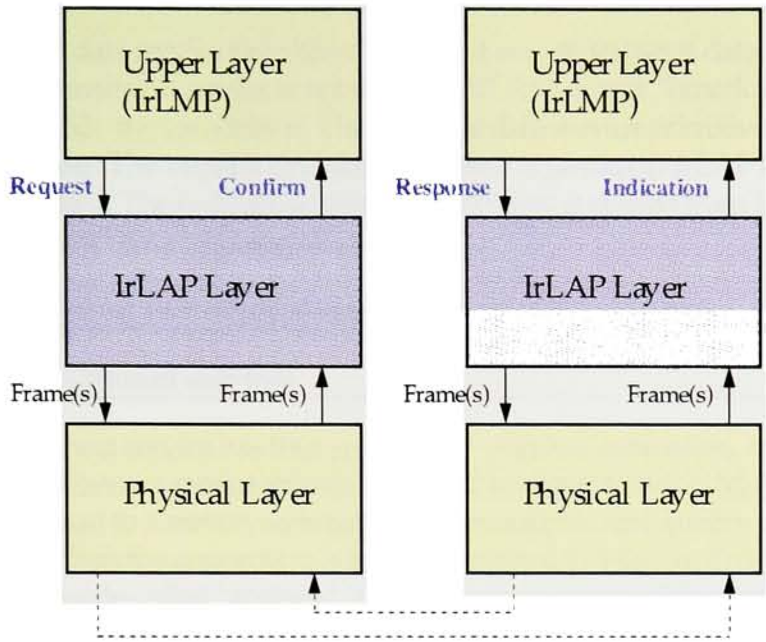


Figure 11. IrLAP primitives used to communicate with the IrLMP and manage the communications processes between devices

6.1.1. Connectionless services

6.1.1.1. Discovery services

The discovery services include three primitives ***request***, ***indication*** and ***confirm***. The ***request*** primitive is used to find out what, is any devices are within communication range and are available for connections. A list of the available devices is returned with the matching ***confirm*** primitive. A device that is discovered by another device's request primitive issues an unsolicited ***indication*** primitive with information about the device that issued the request primitive.

6.1.1.2. Address conflict services

The address conflict services are used to resolve device address conflicts. It includes two primitives - ***request*** and ***confirm***.

After a discovery operation if the discovery log contains entries for more than one device with the same device address, than the ***request*** address conflict service primitive may be used to select new device addresses which are no longer conflicting. The ***confirm*** address conflict service primitive are the same as explained in confirm discovery service expect only those devices with the conflicting addresses will respond.

6.1.1.3. Unit data services

The unit data service primitives provide a way to transmit data outside of a connection but this transmission service is not reliable. All data is sent "broadcast" and cannot be directed to a specific device address. The two unit data service primitives are ***request*** and ***indication***. The ***request*** unit data primitive is passed to IrLAP for the data to be transmitted. The ***indication*** unit data primitive is passed from IrLAP to indicate that "broadcast" data has been received.

6.1.2. Connection oriented services

6.1.2.1. Connect services

The connect service has four primitives - ***request, indication, response*** and ***confirm***. The ***request*** connect service primitive is used to request that an IrLAP connection be established to a station with target device address and quality of service. If the Sniff flag is set true then the connection is being attempted to a device that is using a special low-power mode called "sniffing". Both the target device address and the need for sniffing are determined from the log returned by the discovery services. The ***indication*** connect service primitive to the layer above (IrLMP) of the target device provides the device address of the station requesting that connection and a connection handle and quality of service parameters, both of which become valid if the station chooses to accept the connection by issuing the affirmative ***response*** control service primitive. The ***confirm*** connect service is returned on successful establishment of the connection.

6.1.2.2. Sniffing services

The only sniff service primitive is ***request*** which is used to initiate the special low power connect procedure. This request can be canceled by issuing a request primitive with the cancel flag set.

6.1.2.3. Data services

The data services has two primitives - ***request*** and ***indication***. The ***request*** data service primitive is used to request IrLAP to transmit the supplied user data and has a "Expedited-Unreliable-Flag" which differentiates between reliable, sequenced data or unreliable, expedited, unsequenced data. No confirmation primitives are returned to the sender; because IrLAP will deliver error-free data. The ***indication*** data service primitive is used to pass received user data to the upper layer.

6.1.2.4. Status services

The status service has three primitives - ***request, indication*** and ***confirm***. The ***indication*** status service primitive is used by IrLAP to inform the IrLMP (the upper layer) that the quality of link is under suspect. One of the two possible conditions could exist:

- high level of noise or
- complete termination of the connection activity

If the link quality does not improve than an IrLAP ***indication*** disconnect service is likely. IrLAP uses the ***request*** and ***indication*** status service primitive to provide the IrLMP information about unacknowledged "send" data. If there is any unacknowledged data that hasn't yet been successfully transmitted, then the Unacked-Data-Flag in the ***confirm*** status service primitive is set to true and false otherwise. This however doesn't affect the transmission of the data.

6.1.2.5. Reset services

The reset service has four primitives - ***request***, ***indication***, ***response*** and ***confirm***. The reset causes all unacknowledged data units to be discarded. All counters and timers are reset. A reset only occurs if both ends of the connection agree to it. If the response primitive indicates the reset is not accepted then the reset has no effect on the condition.

6.1.2.6 Disconnection service

The disconnect service has two primitives - ***request*** and ***indication***. This service terminates the logical connection and all outstanding data units are discarded. No confirm disconnect service primitive is needed since the disconnect is always successful.

6.2 Environmental and operational characteristics

6.2.1. Configurations and operating characteristics

The IrDA infrared physical layer characteristics affect the rules to access the IrLAP. These characteristics are:

- point to point and point to multipoint
- half duplex
- asynchronous
- hidden nodes
- narrow infrared cone (15° half angle)
- no collision detection
- the stations will be able to detect the presence of other stations (by detecting the data transmission) even if the stations are transmitting at different baud rates

6.2.2. Data link states

A data link channel can be in one of two basic states:

- **Connection state:** In the connection state the data link channel has two or more nodes that have established a connection and are exchanging control / information frames.
- **Contention state**: The data link channel is in the contention state whenever it's not in the connection state. This condition in two scenarios:

- when the connection is disconnected
- no connection was established

6.2.3. Unbalanced data link

The IrLAP treats the IrDA SIR medium as an unbalanced data link due to its half duplex nature, lack of collision detection, slow speed and various other characteristics.

The unbalanced data link involves two or more participating stations. One station has to be the **primary station** and there can be one or more **secondary stations**.

The **primary station** assumes the responsibility of organizing data flow and unrecoverable data link error conditions. The frames that this station transmits are known as ***command frames***. All transmissions over an unbalanced data link go to and from the primary station and there is always one and only one primary station in the data link. It is preferred that all stations can assume the role of the primary station but those stations which do not can only communicate with stations which have primary capability.

The other stations on the data link are known as **secondary stations** and the frames they transmit are know as ***response frames***.

6.3. IrLAP frame structure

The data and control transmissions on an IrLAP data link are organized in a specific format called a frame. This format carries control information and data between the transmitting station and a receiving station. The IrLAP frame structure allows a receiving station to:

- determine where the frame starts and ends
- ensure whether the received frame is intended for the receiving station or not
- take appropriate actions with the received information
- detect the occurrence of transmission errors in received frames
- acknowledge its receipt of frames to the transmitting station

Each IrLAP frame has a specific format. Each frame is made up of:

BOF	ADDRESS	CONTROL	INFORMATION	FCS	EOF

BOF	**- Beginning of flag; 8 bits**
ADDRESS	**- 8 bit address field**
CONTROL	**- 8 bit control field**
INFORMATION	**- Optional data field**
FCS	**- Frame check sequence; 2*8 bits**
EOF	**- Ending flag; 8 bits**

Figure 12. IrLAP frame format

6.4. Frame type and frame function

There are three general frame formats, which are determined from the content of the Contorl field of the IrLAP frame format (see Figure 12.). The three fields are:

- Unnumbered format (U)
- Information format (I)
- Supervisory format (S)

6.4.1. Unnumbered format (U)

Unnumbered frames are used for:

- Establishing and disconnecting the data link
- Reporting procedural errors
- Transferring data
- Data link management which includes
    - discovering, activating and initializing secondary stations,
    - controlling the response mode of the secondary stations
    - reporting procedural errors which cannot be recovered by retransmission

6.4.2. Supervisory format (S)

Supervisory frames are used for:

- assisting transfer of information although they do not carry information themselves
- acknowledging received frames
- conveying ready or busy conditions
- reporting frame sequence errors and requesting retransmission
- polling the secondary stations by the primary station (with or without the information data to transmit)

6.4.3. Information transfer format (I)

The I field is unrestricted in content. but is a multiple of eight bits. Information frames are used for:

- transfer of data / information that is moved from the data link layer to the layers above the IrLAP

6.5 IrLAP operating procedures

This section explains the procedures that define the behavior of the IrLAP layer during the various phases of its operation. The operation phases are:

- **Link startup/shutdown:** These procedures govern the behavior of the IrLAP when its operation is enabled and disabled.
- **Address discovery:** It determines the device addresses and other key attributes of all stations which have active IrLAP layers and that are within communicating range.
- **Address conflict resolution:** This procedure is used when two or more stations that respond to the address discovery procedure are determined to have selected the same device address. In such a case the stations are informed of the conflict and guided in the selection of new addresses that do not conflict.
- **Connection establishment:** This procedure is used to establish an IrLAP connection to a station whose device address has been determined using the address discovery procedure.
- **Sniff-open:** It comes in play when the device wants to broadcast it's readiness to connect with another device in it's range in a power conserving fashion.
- **Information exchange:** The purpose of this procedure is to govern how the IrLAP layer should exchange information frames using the IrLAP connection.
- **Connection reset:** It is used to rest a previously established IrLAP connection.
- **Disconnection:** This procedure is used to terminate an established IrLAP connection.

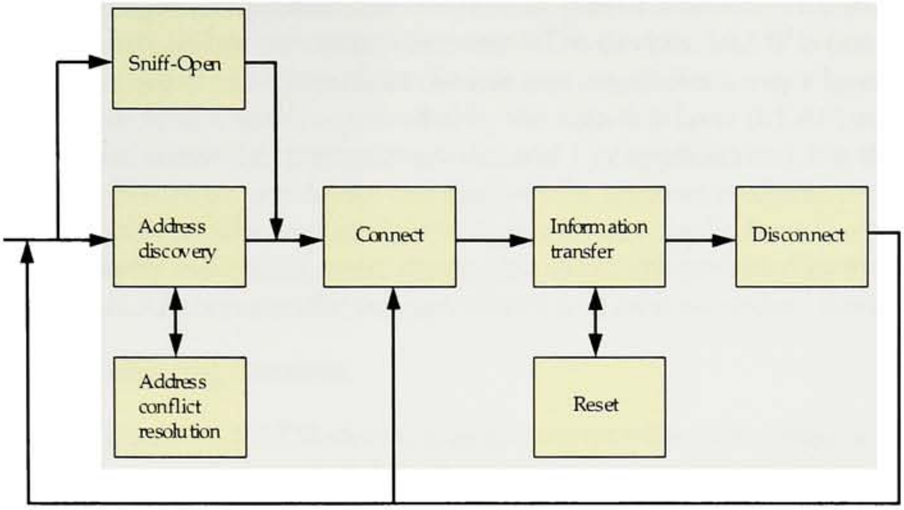


Figure 13. IrLAP operating procedures

A link operates essentially as follows. A device that wants to connect to another device (either by automatic detection via the discovery and sniffing capability of IrLAP or via direct user request). After obeying the media access rules the ***primary*** device will send connection request information at 9600 bps to the other device. This data will include information such as address and other information like the data transfer rate etc. The responding (***secondary***) device after obeying the media access rules return information that contain its address and capabilities. The ***primary*** and the ***secondary*** devices will then change the data rate and other link parameters to the common set defined by the capabilities described in the information transfer. The ***primary*** device will then send data to the ***secondary*** device confirming the link data rate and other capabilities. The two devices are now connected and the data can be transferred between them under the control of the primary device. Once the transfer is complete the link is disconnected. Reset is used to reset a previously established link.

7. IrDA link management protocol (IrLMP) [12]

The IrDA link management protocol (IrLMP) [12] is part of a standard for IrDA devices that support walk-up, ad hoc connection between IrDA devices. IrLMP is one of the three mandatory component of IrDA compliant devices and constitutes a major layer of the IrDA protocol stack. It uses services provided by the data-link layer (IrLAP) and provides services to the client above (i.e., transport entities and / or applications). It is thus the sole client of IrLAP. Software on one device can discover the services available on other devices. The protocol provides support for multiple software applications / entities to operate independently and concurrently, sharing the single link provided by the IrDA Link Access Protocol (IrLAP) between the primary device and each secondary device.

This involves the following elements:

- **Discovery:** It entails each IrDA device maintaining an information base of services that the device currently has available. These services are modeled as objects with attributes that describe the object. This information may be queried from another device.
- **Multiplexing:** This enables independent entities to exchange data over a single IrLAP link.
- **Link Control:** It involves managing the use of the multiplexed link, including provisions for clients that want exclusive control of the IrLAP link connection.

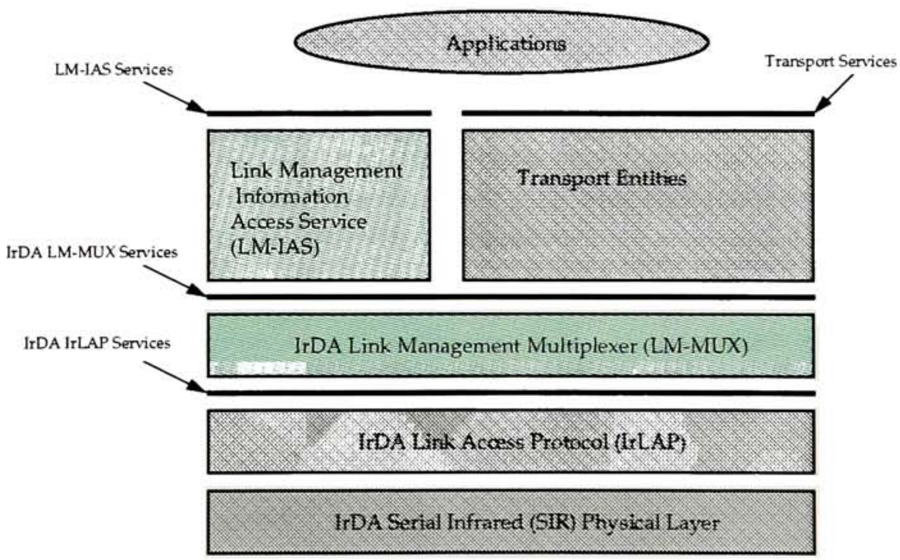


Figure 14. Link management in IrDA architecture

7.1. Architectural overview

Link Management layer has two main components:

- The link management information access service (LM-IAS)
- The link management multiplexer (LM-MUX)

7.1.1. The link management information access service (LM-IAS)

The LM-IAS is an entity that maintains an information base so that other IrDA device can discover what services it has to offer as well as finding out about the device itself. This information is held in a number of objects in the information base. LM-IAS is a direct client of LM-MUX and operates in a client-server manner. Application components that wish to make accessible to peer components in other device describe themselves by creating an object whose attributes carry the essential parameters required to establish a connection between two peers.

The LM-IAS model only defines the outside view of the information held by an LM-IAS entity and defines the format of transmitted data and the operations used to access the information. It does not specify the internal implementation details nor how information is registered within the entity as long as the outside view is the same.

7.1.2. Link management multiplexer

The LM-MUX provides services to both the local LM-IAS entity and to transport entities or applications that bind to the LM-MUX. The LM-MUX provides multiple data link connections over IrLAP.

Besides these two major components the link management layer has **service interfaces** which are provided at two points between the LM-IAS entity and application and by the multiplexer between the multiplexer and its clients. These interfaces are:

- **LM-IAS interface** which provides a mechanism for exchanging information about participating devices and the services they offer.
- **LM-MUX service interface** provides services to both Link Management itself and to its service users at Link Service Access Points (LSAP's) It provides a mechanism to enable multiple data connections over IrLAP, as well as sharing control of the single IrLAP connection between a pairs of stations.

7.2 . Link model

The LM-MUX can have one or more than one LSAP connections active at any one time. These two modes are multiplexed or exclusive.

7.2.1. Multiplexed mode

Multiplexing allows more than one protocol entity to use the single IrLAP link connection between any two IrDA devices independently and concurrently with other protocol entities. But the IrLAP supports a single IrLAP-connection between any given pair of devices. The LM-MUX provides multiple independent LSAP-connections per IrLAP connection. However, it does not provide per LSAP-connection flow control. In multiplexed mode an LM-MUX entity requires that its clients accept any incoming frame. But if the LM-MUX client is not able to accept the data presented, the LM-MUX will discard the data. To ensure reliable data delivery the LM-MUX client must guarantee one of the following conditions:

- that this condition does not arise by implementing an appropriate flow control mechanism on top of the link protocol
- implement an appropriate scheme to retransmit any lost data frames

7.2.2. Exclusive mode

A single service that needs only one application-to-application connection may wish to depend on IrLAP flow-control rather than incur the overhead of a flow-controlled transport protocol. Such services are allowed to request exclusive use of the IrLAP connection. In this mode, since there is only a single LSAP-connection being serviced, flow-control on the LSAP-connection may depend upon IrLAP flow-control. Hence, in exclusive mode reliably delivered I frames are buffered within the receiving LM-MUX until the intended LM-MUX client is capable of receiving them. However, since UI frames are not subject to flow-control they are handled in the same way as they are in multiplexed mode i.e. they are not held indefinitely within the receiving LM-MUX and must be accepted when delivered to an LM-MUX client.

7.3. Link management multiplexer

This section outlines the operation of the LM-MUX. This section describes the external interfaces, service access points, connections, endpoints, internal organization service specification and operating procedures.

7.3.1. External interfaces

The upper layer of the LM-MUX service boundary has three different types of service access points. There also exists the IrLAP service access point used at the lower LM-MUX service interface, i.e. the IrLAP service boundary.

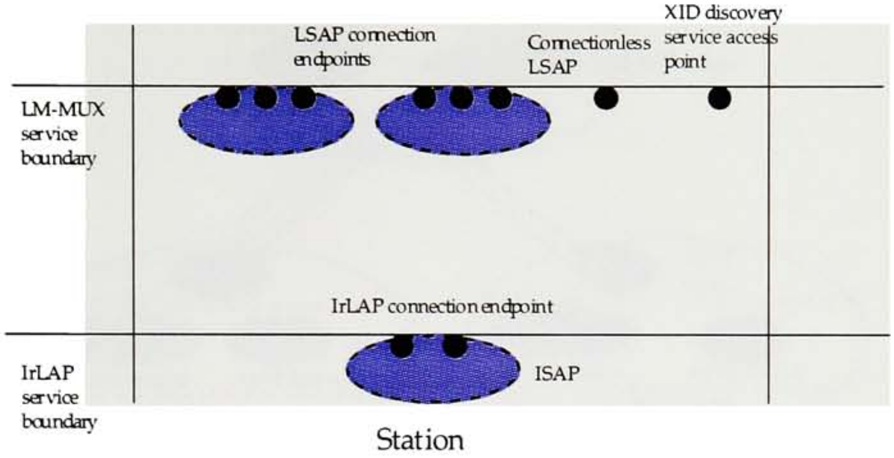


Figure 15. LM-MUX external interfaces

The three service access points are:

- The LSAP_Connection endpoints which include service primitives like LM_Connect, LM_Disconnect, LM_Data and LM_UData.
- LM_ConnectionlessData primitives are invoked at the Connectionless LSAP. LM_ConnectionlessData indication primitives are delivered to all LM_MUX clients that bind to the Connectionless LSAP.
- The XID_Discovery service access point invokes the LM_Discover and LM_Sniff primitives.

Besides the LM-MUX service primitives all the IrLAP service primitives are invoked at on IrLAP-connection endpoint. There is one IrLAP service access point (LSAP) per station.

7.3.2. Service access points, connections and endpoints

The main purpose of the LM-MUX is to provide connection-oriented data transfer services between multiple LM-MUX clients like the transport entities or directly bound attached applications. Peer LM-MUX clients are connected by an LSAP-connection and the LSAP-connections between stations are carried over IrLAP-connections.

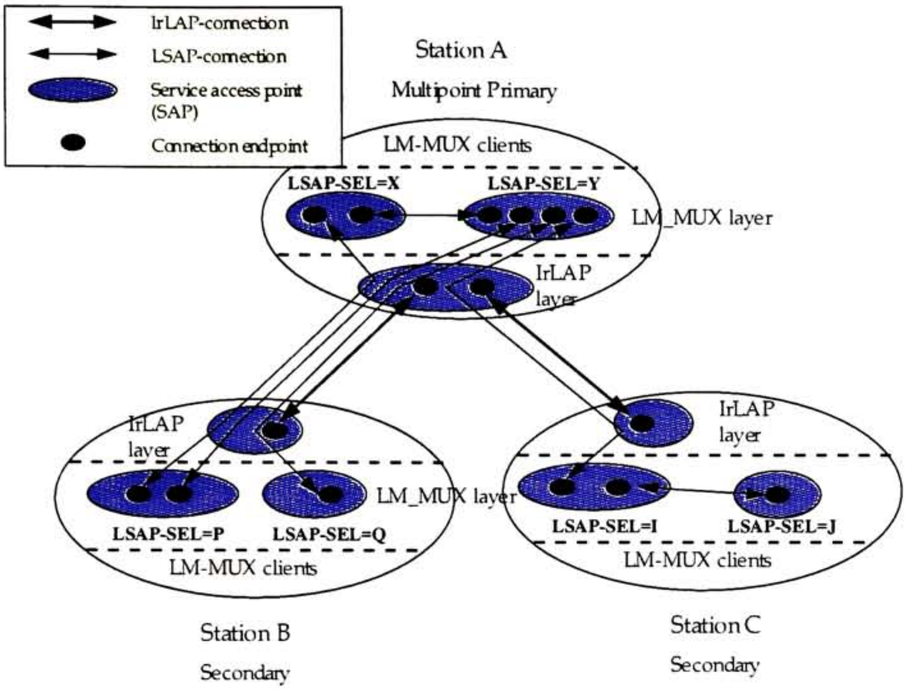


Figure 16. LSAP-connections, IrLAP connections and stations

The above Figure 16. shows the relationships between stations. Within a station LSAP's are distinguished by the value of LSAP-SEL however LSAP-SEL values for each end of an LSAP-connection are carried in LM-PDU's. There is no requirement that the LSAP's at each end of a connection are assigned the same LSAP-SEL value. This leads to the following conclusions:

- There can be no more than one LSAP-connection between the same pairs of LSAP's. This implies that an LSAP may terminate more than one LSAP-connection from the same peer station provided that the other end of the LSAP-connections terminate at distinct LSAP's. For example in Figure 16 the two LSAP-connections from Station A terminate at Station B with the LSAP-SEL =Y but in Station B the LSAP are different (LSAP-SEL = P and Q).
- Within a station it is possible for Intra-Station LSAP-connections to be made that do not use an IrLAP connection. For example in Figure 16 in Station C the LSAP-connection with LSAP-SEL = J does not use an IrLAP connection.
- LSAP-addresses are composed of the LSAP-SEL values but these values are referenced within the scope of the station only. This implies that the X, P and I may all represent the same LSAP-SEL value.
- Only one IrLAP service access point (LSAP) exists per station.
- Multiple LSAP-connections may use of the same IrLAP-connection.

7.3.3. IrLMP service specification

There are three groups of external IrLMP service primitives:

- discovery
- link control and
- data transfer

7.3.3.1. Link management discovery service primitives

The link management discovery process uses the mechanisms provided by the IrDA link access protocol so that the application can find out what other IrDA devices are reachable. The IrDA link management protocol provides basic information for each device it manages to contact. The discovery process has a basic inherent problem that a device may not be able to reply to the request for its address and device addresses may need to change because of address conflicts.

- **LM_DiscoverDevices:** The LM_DiscoverDevices service causes a single IrLAP discovery operation if it is possible i.e. if the link is in contention state. If the link is currently is use, the results of the last discovery operation this device was involved in are returned. This may only include the device at the other end of the link if this device did not instigate the last discovery process. If a conflict in addresses is encountered then IrLMP attempts to resolve each set of conflicting addresses once. After that it will remove all entries with conflicting addresses. It is a required service primitive.

- **LM_Sniff:** The LM_Sniff service is a way to invoke the sniffing service provided by IrLAP. It is invoked at the Station entity and as long as this request is operational no other services are available. The request is operational until another device connects at the IrLAP level or if the request is canceled. The request can be implicitly canceled. It is an optional service primitive.

7.3.3.2. Link management link control service primitives

- **LM_Connect:** After the LSAP for a transport entity on a remote device has been identified, the LSAP for the local transport entity and the remote entity must be connected for data to be sent. LSAP's are bound in pairs and may be at most one LSAP-connection between any given pair of LSAP's. A LSAP service user may request a Quality of Service (QoS) for the IrLAP link. The QoS includes the baud rate, max. turn around time, data size and disconnect threshold. If there are no other LSAP connections or the IrLAP link does not yet exist, an attempt to provide the requested QoS will be made. If the connection succeeds, the actual QoS parameters will be returned. If the actual QoS is not sufficient, it is up to the LSAP service user to disconnect. This service primitive is required.

- **LM_Disconnect:** This service primitive is required and requests that an LSAP connection be broken. A LSAP service user cannot refuse to do this.

- **LM_Status:** This service primitive provides information when to gracefully disconnect. It provides request / confirm pair provides information on whether there is still unacknowledged data in the IrLAP queue. This service primitive is required.

- **LM_Idle:** The LM_Idle service primitive is invoked at a LSAP connection endpoint. It is used to mark the LSAP connection as idle / active. Once the connection is established the LM_Idle primitive is marked to be active. If the service user wants to keep the connection open for a long time without actively using the link, it can choose to inform link management which allows another LSAP service user to bring the station into exclusive mode. Until this service user brings the station back to the multiplexed mode no other service user can become active. When in idle mode, no traffic can be sent from this LSAP endpoint. This is an optional service primitive.
- **LM_AccessMode:** This is an optional service primitive and can change the station from exclusive to multiplex mode and vice-versa.

7.3.3.3. Link management data transfer primitives

- **LM_Data:** When an I frame is sent to the remote LSAP the sender of the data is not told when it arrives. If the underlying IrLAP link layer connection breaks, data may be lost. The sender has no information about the lost data however both LSAP clients will become aware of the potential loss as they will each receive LM_Disconnect indication. This service primitive is required.
- **LM_UData:** Same as above but in this case UI frames are being sent to the remote LSAP. The only difference between this and LM_Data is that UI frames are sent and delivered before any outstanding I frames for the same destination LSAP. This service primitive is required.

7.3.4. Frame formats

Link management controls the content of the DeviceInfo field in the IrLAP discovery process. The DeviceInfo field contains:

- **Service hint mask:** Service hints are useful when devices with different services exist in the same IR space e.g., a laptop, a printer and a modem. The first two octets (DLSAP-SEL and SLSAP-SEL) of the DeviceInfo field contain the IrLMP hint mask. All undefined hints are set to zero. The eighth bit of every hint byte (bit 7, 15, 23, ...) is an extension bit and indicates whether or not an additional hint byte is included in the DeviceInfo field. Table 2 summarizes the current IrLMP hint mask.
- **Device nickname:** The device nickname is useful when many devices of the same type and similar services exist in the same IR space e.g., several PDA's. The device nickname is found in the DeviceInfo field may be a truncated version of the name returned as the value of the "Device" object's DeviceName attribute. The maximum number of bytes in the DeviceInfo field must not exceed 23 bytes.

Byte# 1	
Bit	Function
0	PnP compatible
1	PDA / Palmtop
2	Computer
3	Printer
4	Modem
5	Fax
6	LAN access
7	Extension

Byte# 2	
Bit	Function
8	Telephony
9	File Server
10	Reserved
11	Reserved
12	Reserved
13	Reserved
14	Reserved
15	Extension

Table 2. IrLMP service hints

- **LM-PDU Formats:** All the LM-PDU frames are sent as IrLAP data frames. Link Management uses a two-octet header within the IrLAP data frames encoded as follows:

7	6 5 4 3 2 1 0	7	6 5 4 3 2 1 0
c	DLSAP-SEL	r	SLSAP-SEL

where "c" is the control bit. If the control bit is set to 1 it indicates that the frame is a command frame otherwise if it is set to 0 then the frames is a data frame. The r bit is reserved for future extensions and currently should be set to 0.

The **data transfer frames** are encoded as follows:

7	6 5 4 3 2 1 0	7	6 5 4 3 2 1 0	
0	DLSAP-SEL	0	SLSAP-SEL	Data .....

The **link control frames** are encoded as follows:

7	6-0	7	6-0	7	6-0	
1	DLSAP-SEL	0	SLSAP-SEL	A	opcode	parameters

When the A bit is set to 0 indicates a command request at the source side and should be interpreted as a command indication at the destination side. When the A bit is set as 1 it is command response at the source side and a command confirmation at the destination side. All frames are sent as reliable data.

7.3.5. Detailed description

This section explains the operating procedures of the IrLMP which include station control. IrLAP link connection control and LSAP-connection control.

7.3.5.1. Station control

7.3.5.1.1. Purpose of the station control

The station control finite state machine (FSM) is responsible for the coordination of the Link Control and LSAP-Connection FSM's. The station control FSM also directly controls the discovery process, address resolution, sniffing and access mode. With the exception of the IrLAP data indication all incoming IrLAP events are initially handled by the station control FSM. Only one instance of this FSM exists.

7.3.5.1.2. Overview of the station control

The major phases of activity with the station control FSM are:

- Discovery and address resolution which are handled by the states DISCOVER and RESOLVE ADDR.
- LM-MUX transitions between multiplexed and exclusive mode, handled by the states EXCLUSIVE PEND, EXCLUSIVE and READY PEND.
- Primary / Secondary role exchanger, handled by the state ROLE EXCHANGE.
- Sniffing, handled by the state SNIFF.

The **READY** state is heart of all this activity. Discovery occurs when an LM_DiscoverDevices request primitive is received when there are no established or establishing IrLAP connections. IrLAP returns conflicting DeviceInfo record i.e. there are multiple entries for the same device address. Then address resolution is performed to ensure that the DeviceInfo records that are returned relate distinct device addresses. However if the IrLAP connection already exists when the LM_DiscoverDevices is returned then the cached results of the previous operation are returned, possibly

augmented with further DeviceInfo records reported to station control by IrLAP via IrLAP_Discover indication primitives.

The **READY** state guards the start of a transition from multiplexed to exclusive mode by ensuring that the local conditions are met before allowing the transition to commence. If the transition is being made in response to a remote request and local conditions permit the transition is made to the **EXCLUSIVE** state. If the transition is the result of a local LM_AccessMode request and the local conditions allow an AccessMode request, then LM-PDU is sent to the remote station control FSM and the transition is made to the **EXCLUSIVE PEND** state where a result from the remote peer is awaited. If the transition to exclusive mode is acceptable to the remote peer a further transition to the **EXCLUSIVE** state occurs. Otherwise a reverse transition to the **READY** state is made and any local locks previously established are released.

A similar set of transitions take place when moving from the exclusive mode back to the multiplexed mode. In this case the mode change from exclusive to multiplexed may not be refused by the remote peer, so there is no possible transition from **READY PEND** back to **EXCLUSIVE**.

Primary to secondary role exchange is requested by a point-to-multipoint capable LM-MUX if it needs to establish more than one IrLAP connection. In this case the requesting station control invokes the IrLAP_Primary service and transitions to the state ROLE EXCHANGE. The remote station control will permit the role exchange in all states where there is just a single IrLAP connection. If the exchange is successful the station control FSM transitions back to the READY state progressing the LM-Connect request that indirectly initiated the IrLAP connection attempt. Otherwise the station control FSM transitions back to the READY state after failing the exchange request.

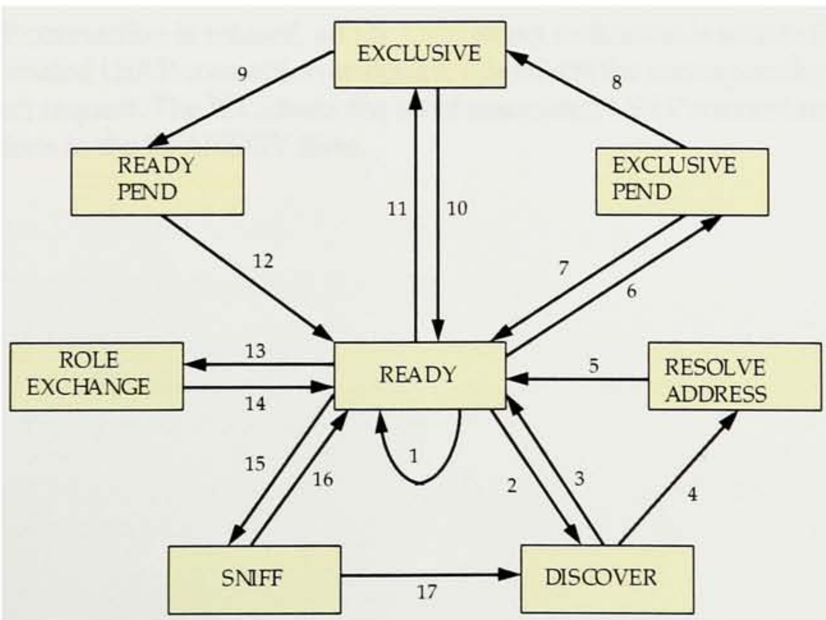


Figure 17. Station control state transition diagram

7.3.5.2. IrLAP connection control

7.3.5.2.1. Purpose of the IrLAP connection control

An instance of an IrLAP connection control FSM (ICC FSM)assists in the establishment of an IrLAP-connection and the association of LSAP connections with that IrLAP link. When all LSAP-connections associated with the IrLAP connection cease, the ICC FSM ensures that the IrLAP connection is disconnected.

7.3.5.2.2. Overview of the IrLAP connection control

An instance of the ICC FSM is associated with each IrLAP connection. It maintains and association between the LSAP_connections using a given IrLAP connection and the IrLAP connection itself. The ICC FSM is initialized to the **STANDBY** state.

In the **STANDBY** state the ICC FSM is waiting for either:

- a local request to establish an IrLAP connection which will occur as a result of an LM_Connect request having been invoked at a local LSAP-connection endpoint, or
- an incoming IrLAP connection as a result of a similar action at a remote peer. Such a signal via an IrLAP_Connect indication primitive is accepted unconditionally and the ICC FSM transitions to the **ACTIVE** state.

In the **U_CONNECT** state the ICC FSM awaits the outcome of an attempt to form an IrLAP connection. In this state, requests to open an IrLAP connection to the same destination result in the requesting LSAP-connection endpoint being added to the set of associated LSAP connection endpoints.

If the IrLAP connection is refused, an LS_Disconnect indication is sent to the ICC FSM to each associated LSAP-connection endpoint; this rejects the corresponding LM_Connect request. The ICC clears the set of associated LSAP connection end-points and transitions to the STANDBY state.

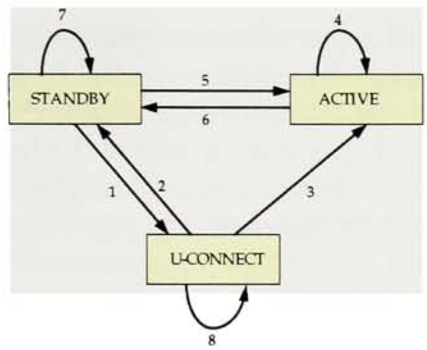


Figure 18. IrLAP connection control state transition diagram

Otherwise if the IrLAP connection is permitted an LS_Connect confirm primitive is invoked at the ICC FSM of each LSAP-connection endpoint associated with the IrLAP connection. This indicates the availability of an open IrLAP connection. The ICC FSM transitions to the active state.

In the **ACTIVE** state the ICC FSM performs the following functions:

- continues to associates new LSAP-connection endpoints with the IrLAP connection.
- removes LSAP-connections that have ceased to use the IrLAP connection.
- if no LSAP connections associated with a given IrLAP connection exist then the ICC FSM may disconnect the underlying IrLAP connection and return to the **STANDBY** state

7.3.5.3. LSAP-Connection control

7.3.5.3.1. Purpose of the LSAP-connection control

An instance LSAP-connection control (LCC) FSM maintains the state of an LSAP-connection that terminates within the station. there is one instance of this FSM for each LSAP-connection endpoint within the station.

In addition to this the FSM provides the LM_Idle service and participates in the establishment and enforcement of the LM-MUX exclusive mode.

7.3.5.3.2. Overview of the LSAP-connection control

The LCC FSM is initialized in the **DISCONNECT** state and each LSAP-connection endpoint within a station has an instance of this FSM .

The connection is opened with the receipt of an LM_Connect request primitive from the LSAP-connection endpoint. This triggers the invocation of an LS_Connect request to associate the resulting LSAP-connection with its supporting IrLAP connection. This results in a transition to **SETUP-PENDING**.

LS_Connect request is serviced by station control which will attempt to establish an IrLAP connection. If a suitable IrLAP connection exists station control signals the availability of a suitable IrLAP connection by the invocation of an LS_Connect confirm event at the FSM. This causes LCC FSM to transition to the **SETUP** state and sends a connect LM-PDU to its intended peer. If station control was unable to associate the LSAP-connection endpoint with an IrLAP connection it returns a LS-Disconnect indication (reason = noIrLAPConnection). The LCC FSM transitions back to the **DISCONNECT** state and issues an LM_Disconnect indication back to the service user.

When the connection confirm LM-PDU is received the FSM issues an LM_Connect confirm to the service user and transitions to the DTR state. Now the user data can be exchanged over the LSAP-connection through the use of LM_Data and LM_UData services. If a connect LM-PDU arrives while the FSM is in the SETUP state a race condition occurs and the FSM transitions back to the **DISCONNECTED** state and issues an LM_Disconnect indication (reason = connectionRace) to the service user. Likewise an LS_Disconnect indication or the arrival of an Disconnect LM-PDU also cause the failure of the LSAP-connection.

Passive establishment of an LSAP-connection occurs when a connect LM-PDU arrives at an FSM in the **DISCONNECT** state. It first issues an LS_Connect request to bind the LSAP-connection endpoint to the supporting IrLAP connection and transitions to the **CONNECT-PEND** state. Upon receipt of an LS_Connect confirm, the incoming LSAP connection is signaled to the service user by an LM-MUX client. If the user returns an LM_Disconnect request then the FSM returns a Disconnect LM-PDU to its peer (reason = userRequest) and issues an LM_Disconnect request to disconnect itself from the IrLAP connection and transitions to the **DISCONNECTED** state. If the user accepts the incoming LSAP connection by issuing an LM_Connect response a connect confirm LM-PDU is sent to the peer FSM and the local FSM transitions to the DTR state. Once again user data may now be exchanged using the LSAP connection through the use of LM-Data and LM_UData services.

The LM_Idle service is implemented by transitions between data transmit ready (**DTR**) and **DTR-IDLE** state. LM_Idle services may only be invoked in the **DTR**, **DTR-IDLE** and **DTR-LOCKED** states. When the station establishes exclusive mode operation on behalf of another LSAP-connection the FSM transitions to the **DTR-LOCKED** state. From this state the LSAP-connection may be disconnected with a resulting transition to **LOCKED** out which prevents new connections being established when the station is in exclusive mode.

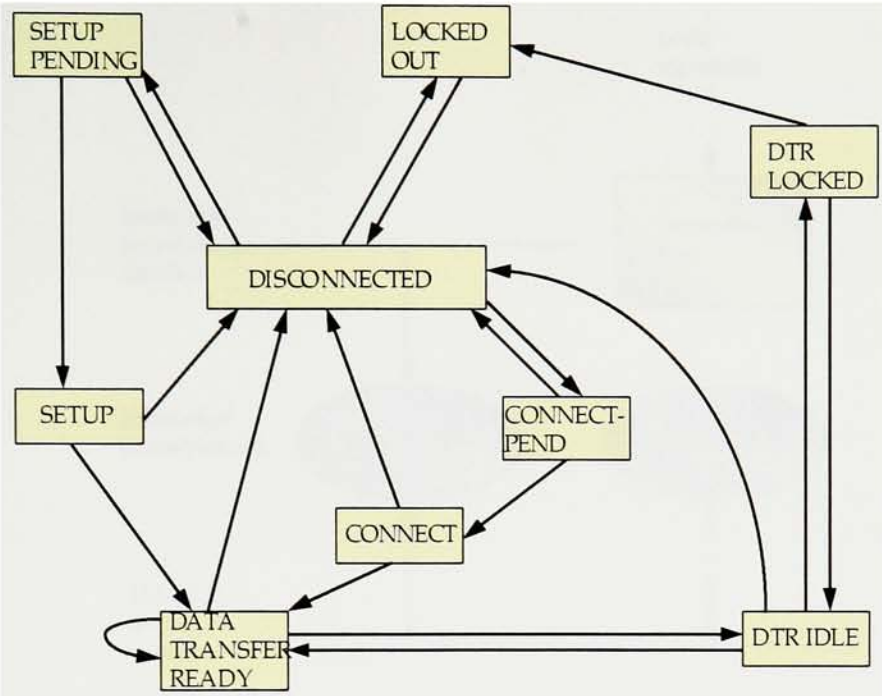


Figure 19. LSAP connection control transition diagram

7.4. Information access service

The information access service (IAS) is a direct client of LM-MUX and operates in a "client-server" manner. Applications components that wish to make themselves accessible to peer components in other service "describe" themselves by creating an object whose attributes carry the essential parameters required to establish a connection between the two peers. An application component seeking a peer application component inspects the objects within the remote LM-IAS information base. Assuming a suitable object exists, the connection parameters are retrieved and the mechanism, which is accessible at the top of the LM-MUX is used to enumerate the available devices. The resulting list of devices may be sorted on the basis of the hints information supplied in discovery responses.

The IAS maintains information about the services provided by the IrDA device and also provides operations for remotely accessing the information base on another device. This information is stored in a different objects in the information base thus providing a simple and uniform way for services to advertise their presence and any information needed to access them. The information defines the external conceptual view of the information held by an IAS and does not dictate the internal organization

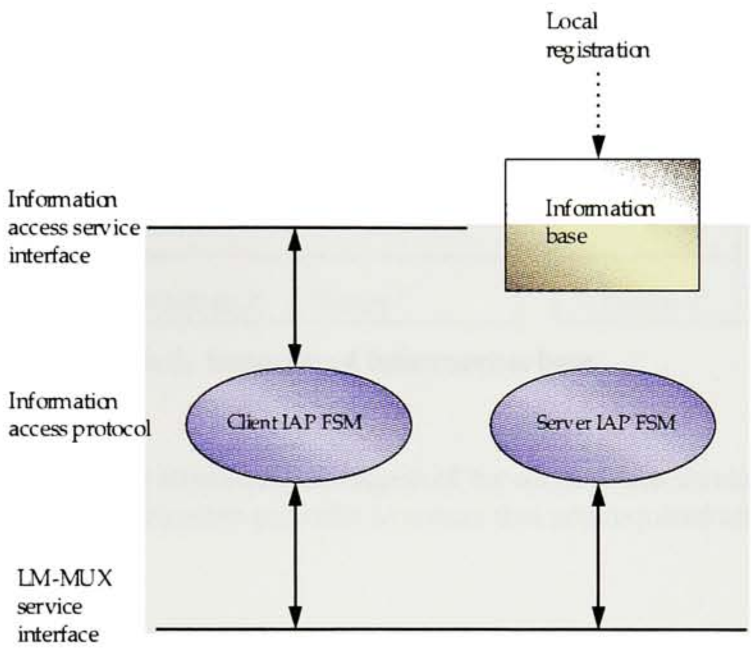


Figure 20. Internal architecture of the information access service (IAS)

The information access protocol (IAP) is the means by which two IAS entities communicate. It is a command / response protocol where each operation has results, indicating success or failure. The protocol uses the reliable data transfer of the IrLAP. There is one instance of server IAP finite state machine for each device that can be contacted and one instance per contactable device of the client IAP finite state machine if this device provides the query primitives.

7.4.1. Information model

Each service, including all other clients of the multiplexer, may provide information for an object in the information database.

Each object in the information database has:

- a class name for the object
- an identifier which uniquely identifies the object within the device
- a variable number of attributes

There may be several objects of the same class. Each attribute consists of a name that identifies the storage slot within its objects and a typed value. Compound types are not supported. The following example shows a possible configuration with three objects, the "IrDevice" object and two services, "getData" and "setData".

Object 0:	Class "IrDevice"
"Device Name"	"Printer"
"IrDA Support"	Binary Data

Object 1:	Class "getData"
"Attribute 1"	1
"Attribute 2"	"getDataString"
"Attribute 3"	"Binary"

Object 2:	Class "setData"
"Attribute 1"	2
"Attribute 2"	"setDataString"
"Attribute 3"	"Binary"

Table 3. Example of information base

A service designer defines the attributes that objects of the service class should provide. It is the responsibility of the information provider to ensure that any required attributes are provided.

7.4.2. Service primitives

The IAP provides operations to:

- identify all the objects currently in the information base
- access attributes with an object
- query all the attribute names of a given object
- provide a list of attribute values for an attribute in a particular class if there is more than one object of that service class. This is also referred to as the fast access mechanism.

The IAS only provides "read only" access to the attributes and does not allow "write" access to change the attribute values.

7.5. Working of the information access protocol

IAP, like any other client protocol running over LSAP-connections, maintains its own flow control. The acknowledgment frames are used as a low level flow control mechanism. IAP ensures that only one unacknowledged frame is outstanding at any one time for each connection.

There are two finite state machines per IrLAP link; one for initiating calls, one for processing calls. The two machines are independent of each other but one connection between the sever machine on one device and the client machine on the other side is always maintained. However there can at most be one call in progress between a particular client-server pair.

Both the client and the server have their individual FSM's. The discussion of those FSM's is out of scope of this paper[1].

[1] For complete details of the IAP and the explanation of the FSM of the client and the server engine please refer to Infrared Data Association Link Management Protocol Version 1.0

8. IrDA transport protocols (IrTP & Tiny TP)

8.1. Infrared Transport Protocol (IrTP)[13]

IrDA transport protocol [13] provides an optional (not required for IrDA compliance) solution by recommending a generic flow-control method. IrTP specifies how the ISO 8073 Class 2 Transport Protocol is used in an IrDA environment, providing multiple independent flow controlled information streams between IrTP clients. Thus IrTP multiplexes multiple transport connections over one or more connections.

8.1.1. Problems without having IrTP

The relevance of IrTP is particularly relevant in multi-threaded environments where multiple applications may wish to share the IrLAP connection between the same pair of devices. Same is true when there are multiple logical streams between a single pair of application components. Typical example are separate streams for file sharing, print redirection and COMM port redirection for a virtual docking application; separate control and data streams between a workstation and a modem via an IR connection.

A simple solution could be to provide a multiplexing field as the first field within IrLAP I frames. The received packets could then be streamed to the right client based on the first field in the I frame. However this solution may not work if the intended recipient application is busy servicing a higher priority task and may not be reading the incoming stream. The IR subsystem could buffer the incoming data until the application is ready to receive them but it will soon run out of buffer space. Then the two possible options are:

- Throw the packet away but this is unacceptable because it will make the IrLAP unreliable.
- Flow control the data link but if one link is busy it can block other data streams using the same data link. This will lead to deadlock problems.

The solution to this problem is to ensure that each stream has its own flow control that may be independently applied when the buffer space allocated to that stream runs out of space. This ensures that data is queued at the sender before the underlying data link runs out of receive buffers. Indeed buffering in the data link layer may be reduced since there should always be application stream buffers available for in bound I frames. If application stream buffers are not available then the application-to-application flow control mechanism is defective.

8.1.2. Purpose of IrTP

Thus the **purpose** of the IrTP is to provide

- application-to-application flow control on a per transport connection basis and in general it must allow multiple transport connections to operate over a single IrLAP / IrLMP connection
- error control (recovery from lost packets) is handled by the IrLAP and provided data is not discarded between the data-link and the transport there is no need to duplicate error control at the transport layer
- graceful disconnection
- more multiplexing

8.2. Tiny TP

Tiny TP defines a credit based flow control scheme and relies on LM-MUX for multiplexing while providing

- independently flow controlled transport connections
- Segmentation and reassembly of arbitrary sized PDU's

9. IrCOMM and how it changes the current printing model

This section defines IrCOMM [14], the emulation of Serial and parallel ports over the IrLMP / IrLAP protocol stack. This protocol is currently being developed by IrDA with major contributions from Hewlett-Packard, Lexmark, Sharp Corporation, NTT, Nokia and Counterpoint Systems Foundry. The main thrust comes from the many printing and communication applications which presently use the RS-232 cabling to communicate with other devices via serial and parallel ports. This created the need to make the IrDA protocol stack accessible via API's so that most of these "legacy" applications, applications that know about serial or / and parallel ports but know nothing about the IrDA protocols, can run over the IrDA. The IrDA assumes that the new applications will not rely on using the IrCOMM emulation and rather use the IrDA protocols capabilities directly.

9.1. Current printing model

The current printing model consists of several steps from when the user invokes the print command on the computer to the time the printed page actually comes out of the printer.

The following steps [16] are involved in printing a document (refer to figure 22, the numbers in the figure correspond to the steps below):

Step 1: Create the document you want to print.

Step 2: Save the document in the graphical user interface (GUI) format of the platform that you are using. In Microsoft Windows this is in graphics device interface (GDI) format, on a Macintosh this would be in Quickdraw and on Sun Unix in the X format.

Step 3: Perform the conversion process that maps the GUI format into the appropriate printer's language using the selected printer driver. It may involve any of the following options:

- Convert GUI format to a Page Description Language (PDL) such as PostScript (PS) or Printer Command Language (PCL)
- Stay with the same GUI format and have the GUI interpreter in the printer rasterize them (GDI solution)
- Rasterize the GUI commands

Step 4: Perform compression on the data that will be transmitted between the computer and the printer. This increases the speed of transmission because of the reduction in the size of data transmitted. This is an optional step and the print driver has the option to perform compression on the output file. Due to this reason step 4 is shown dotted in the figure 22.

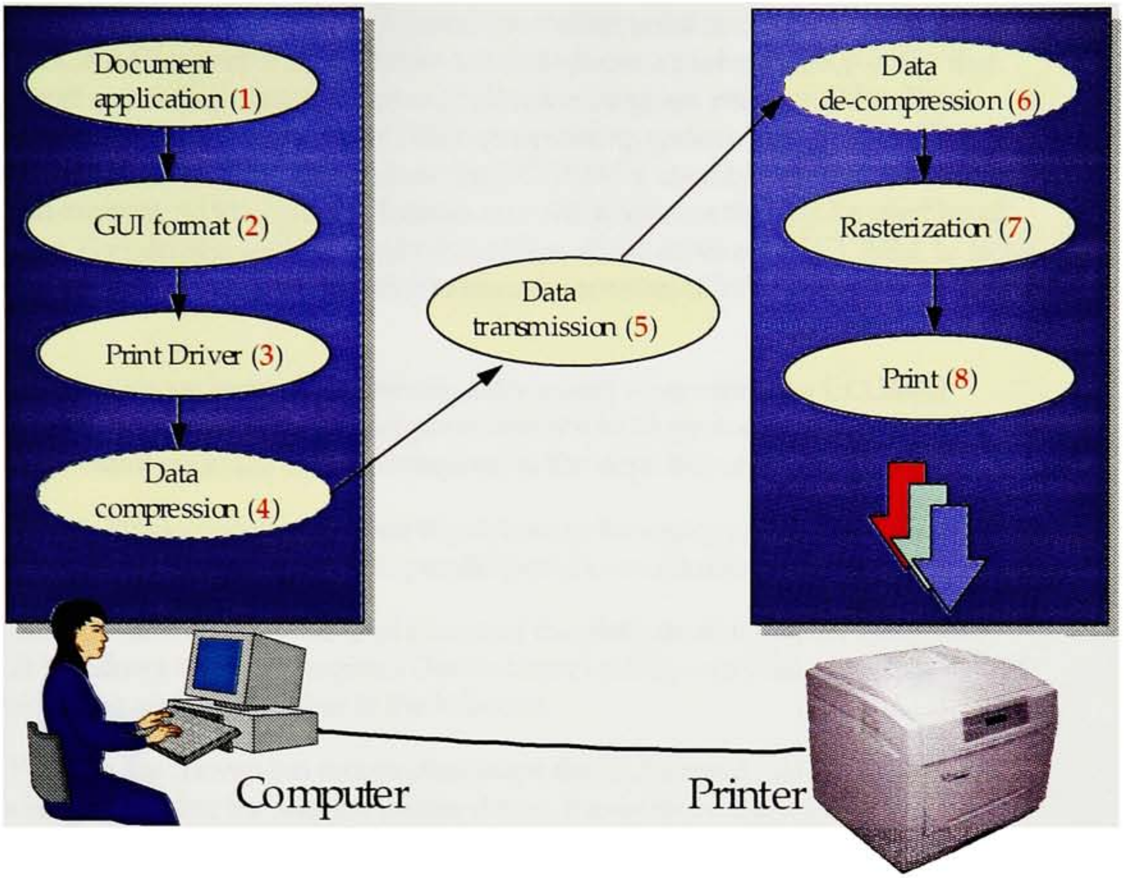


Figure 21. Current printing architecture (Adapted from the "Page Description Languages: The Ups, The Downs and The Potentials" by Ta L.)

Step 5: This step involves the transmission of data from the printer driver to the printer using the cable connecting the computer and the printer.

Step 6: If step 4 has been performed and the data arrives in the compressed format to the printer then it must be decompressed. Again step 6 is optional and depends if step 4 has been applied or not.

Step 7: If the data is in the rasterized form then skip to step 8 else use the appropriate printer's interpreter to produce the raster data (pixels).

Step 8: Send the raster data to the marking engine to produce a printed page.

9.2. IrCOMM printing model

IrCOMM defines a protocol that can be used to emulate serial and parallel ports. In most systems IrCOMM is a part of a port driver which includes a port emulation entity that must support an existing communication application program interface (API). These communication API's are different for different operating systems and devices. The IrCOMM protocol does not focus on how the IrCOMM is used by the port driver to emulate an existing API but instead focuses on a set of services that can be used by all port drivers. Port drivers are not required to utilize all the services of IrCOMM. In fact it is the job of the port driver implementor to map the services of IrCOMM to the particular system.

The following steps are involved in printing a document when using the IrCOMM protocol emulation of serial or parallel ports over the IrDA protocol stack (refer to figure 23 where the numbers in the figure correspond to the steps below):

Step 1: Create the document you want to print using the legacy application. These legacy applications utilize conventional serial / parallel port communication interface.

Step 2: Save the document in the GUI format of the platform that you are using. In Microsoft Windows this is in Graphics Device format (GDI), on a Macintosh this would be in Quickdraw and on Sun Unix in the X format.

Step 3: Perform the conversion process that maps the GUI format into the appropriate printer's language using the selected printer driver. It may involve any of the following options:

- Convert GUI format to a Page Description Language (PDL) such as PostScript or Printer Command Language (PCL)
- Stay with the same GUI format and have the GUI interpreter in the printer rasterize them (GDI solution)
- Rasterize the GUI commands

Step 4: The port emulation entity maps a system specific communication interface (API) to the IrCOMM services. It is also responsible for device discovery and LM_IAS queries. The port entity plus IrCOMM make up a port driver.

Step 5: This step is performed on the host computer and uses the IrDA protocol stack to establish a reliable IR link for half-duplex serial data communication. It consists of the following sub steps:

- The IrCOMM protocol layer provides a transparent data stream channel and control channel over an IrLMP link or Tiny TP link.
- The next layer Tiny TP provides a data stream channel to IrCOMM along with a flow control mechanism (refer to section 8.0 for more details).

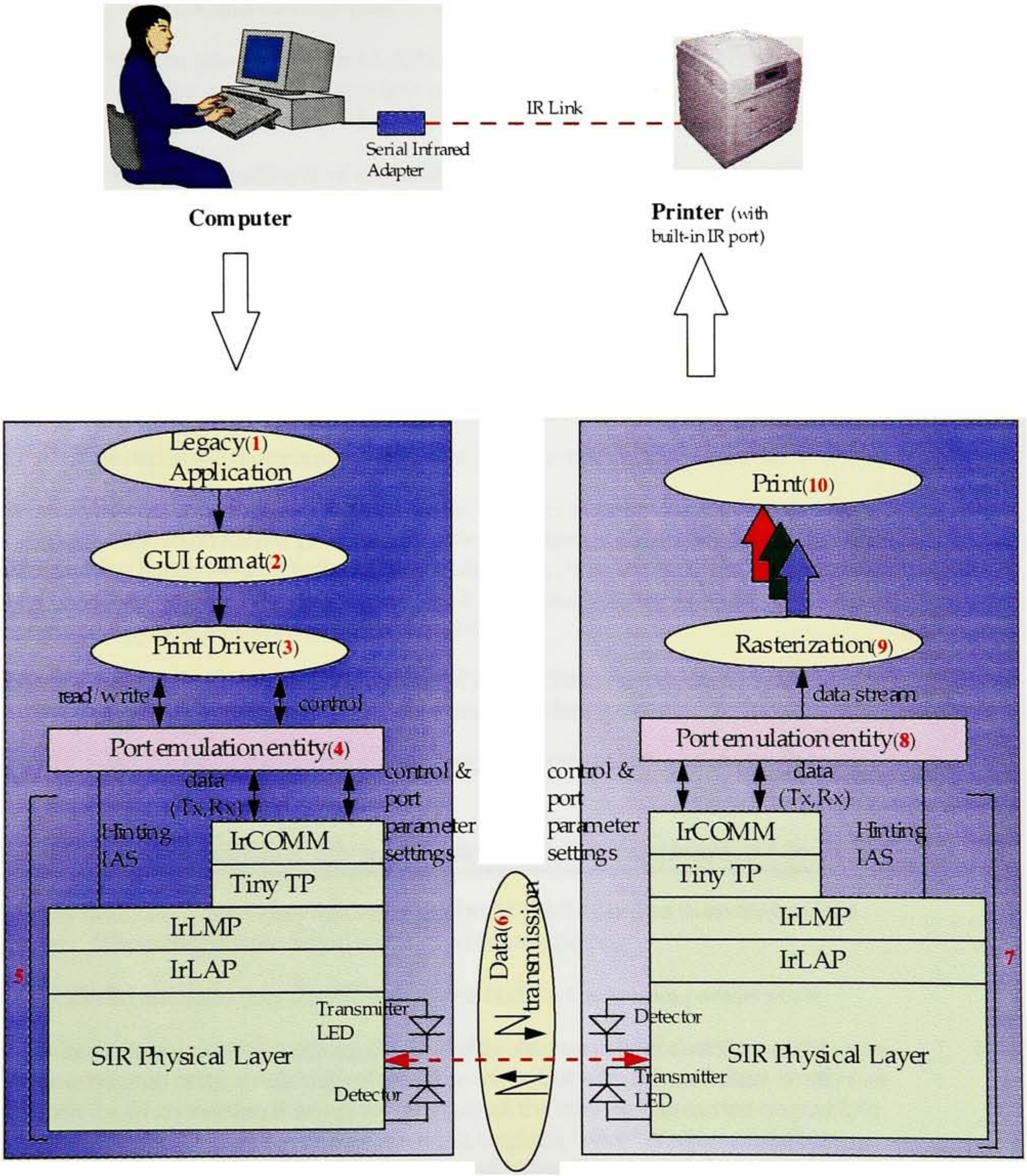


Figure 22. Infrared based printing model (using IrCOMM)

- The layer below Tiny TP is the IrLMP which provides multiplexed channels on top of an IrLAP connection known as the LM-MUX and location of peer application components supported by LM-IAS which is a direct client of LM-MUX (for more details on the operation of the LM-MUX and LM-IAS refer to section 7.3 and section 7.4 respectively).
- The next layer is the IrLAP which provides the functions of the data link layer and controls the flow of data (section 6.0 provides the detail explanation of the IrLAP).
- The lowest layer of the IrDA protocol stack is the Serial IR (SIR) physical layer which provides a half-duplex serial data interconnection (section 5.0 explains the SIR physical layer).

Step **6**: This step involves the transfer of data using the IR link. The transmitter consists of one or more light emitting diodes (LED's), usually connected in series and driven by square waves from an encoder and the receiver consists of a photodiode followed by an amplifier and decoder. Using the transmitter and receiver the computer and the printer can transfer data and control information across the IR link.

Step **7**: This step is the reciprocal of step 5 and is performed on the printer side.

Step **8**: The port emulation entity maps the IrCOMM services to the system specific communication interface (API). The port emulation entity on the printer side by providing this mapping hands the data to the rasterizer depending how the conversion process in the step 3 had been applied. It is also responsible for device discovery and LM_IAS queries. The port entity plus IrCOMM make up a port driver.

Step **9**: If the data had already been rasterized in step 3 then skip to step 10 else use the appropriate printer's interpreter to produce the raster data (pixels).

Step **10**: Send the raster data to the marking engine to produce the printed page.

9.3. Differences between the wired and the IrDA communication model

To fully understand the issues that are related to IrCOMM one has to understand the primary differences between wired and IrDA communication.

- IrCOMM emulates only RS-232 serial ports and the Centronics parallel ports
- Wired communication methods can send data streams in both directions at the same time because of the availability of multiple wires, But with infrared there is only one path the IR connection through air. To carry all the information carried on multiple wires in case of wired communication on a single IR "wire" is accomplished by subdividing the packets into data and control paths. Thus logical data and control channels are created.

- IrDA protocols send packets one way at a time. Bidirectionality in IrDA devices is achieved by taking turns which is know as "turning the link around". This happens every 500 msecs and can be changed to suite the particular applications. This latency makes it impossible to perfectly emulate the wired COMM environment and very timing sensitive operations will not work over IrCOMM emulation.

- IrCOMM is targeted only for the "legacy" applications but IrDA protocols have very different procedures and API's from wired communication. To make the IrCOMM communication process transparent to the end user of the "legacy" applications IrCOMM protocol has to map IrDA specific operations into normal COMM operations. For example if a user is using any graphical package or a word processor and want to print via IR driver using the IrDA protocol stack, the application first has to "discover" the printer in the IR space and then check the printer's IAS to find information needed to connect. The application knows nothing about this and has to be handled by the IrCOMM emulation.

IrCOMM is a complete communication path between two applications running on different devices with a communication segment between them. The communication segment may consist solely of IR (direct connect) or IR connections to a network (indirect connect). In the case where the communication segment is a network, IR is used for the paths between the device and a networking connection device like a modem. Thus two types of devices exist that IrCOMM must be capable to communicate with. These are:

- **Type 1** devices are those devices which normally act as communication endpoints. Type 1 devices include computers and printers.

- **Type 2** devices are those devices which are a part of the communication segment. Typical example of a Type 2 device would be a modem.

The IrCOMM protocol does not make a distinction between these two device types in the protocol because the information transferred between two IrCOMM devices is the same for both type 1 and type 2 devices. Type 2 device needs some additional information which is ignored by the type 1 devices. Figure 21(a) shows the combination between a two Type 1 devices and figure 21(b) shows the communication model between a Type 1 and Type 2 device.

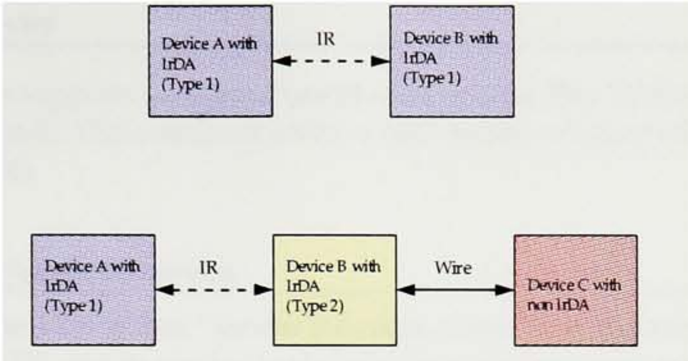


Figure 23. IrCOMM communication model between (a) Two Type 1 devices (b) Type 1 and Type 2 device

9.4. IrCOMM emulation services

IrCOMM emulates serial and parallel ports with four different types of services. These services can be grouped in two categories, depending on whether a control channel is supplied and the type of flow control used. These are:

- Raw service
- Cooked service

9.4.1. Raw service

This service only provides a data channel. Only one service falls into this category which is the 3-Wire raw service.

9.4.1.1. 3-Wire "raw" service

In this case only the data channel is emulated. The term 3-Wire comes from the fact that only three circuits of the RS-232, which are needed for full duplex communication, are emulated. The main attributes of the 3-Wire Raw services are:

- This service can only be used if a single non-IAS exclusive connection is acceptable. All others connections must be closed before it can be established and others must wait until the raw connection is closed before they can connect.
- In this case only the data channel is emulated.
- It works for both the serial or parallel ports.
- The 3-Wire service merely provides a raw channel for the movement of data and no control channel is available to communicate information about the state of other leads

and software control settings. A service which employs 3-Wire raw must be able to do without the control channel.

9.4.2. Cooked service

The cooked service supports a control channel and employs Tiny TP flow control (will be explained in section 8). Three different services fall into this category which are 3-Wire, 9-Wire and Centronics.

9.4.2.1. 3-Wire "cooked" service

As in the case of the 3-Wire "raw" service the name comes from the comes from the fact that only three RS-232 circuits needed for full duplex communication are emulated. Like the 3-Wire "raw" service, the 3-Wire "cooked" service works for both the serial and parallel ports. However there are some key differences between the two, which are:

- The 3-Wire "cooked" service is not limited like the 3-Wire "raw" service to a single IrLMP connection.
- 3-Wire "cooked" service uses Tiny TP flow control so that it may coexist with other connections that employ higher level flow control (like IrLMP not IrLAP). It can also coexist with other "cooked" IrCOMM connections.
- 3-Wire "cooked" service supports a control channel for sending control information like the data channel for sending the data.
- This service uses a complex frame format to accommodate the flow control and the control channel overhead along with the data.

9.4.2.2. 9-Wire "cooked" service

The name 9-Wire comes from the fact that this service emulates 9 circuits of an RS-232 interface. Some of the key distinguishing features of this service are:

- This service emulates the serial port only
- 9-Wire service, like the 3-Wire "cooked" service, uses the same Tiny TP flow control and control channel mechanism.
- The 9-Wire is capable of sending the states 6 more circuits of the RS-232 than the 3-Wire "cooked" service over its control channel.

9.4.2.3. Centronics "cooked" service

This service is intended to emulate the function of a standard Centronics interface. The key distinguishing features of this service are:

- This service emulates the parallel port only.

- It uses the Tiny TP flow control mechanism like the 3-Wire "cooked" and 9-Wire "cooked" service.
- Centronics service uses the same control channel mechanism used in the 3-Wire "cooked" service.

10. Plug and play (PnP) extensions to link management protocol

Plug and play is both a design philosophy and a set of PC architecture specifications to make the computer, add-in hardware devices, drivers and underlying operating systems work together automatically without user intervention. To make such a system possible all the components need to be PnP compatible. The components of a fully PnP system consist of the following:

- PnP operating system
- PnP Basic Input Output System (BIOS)
- PnP hardware devices with drivers

If none of the above three components support PnP the user needs to set card jumpers and switches manually and load device drivers manually. If only the operating system supports PnP but other components do not support Plug and Play, user intervention is reduced but not eliminated completely. PnP operating system can still provide tools to aid the user in hardware setup and automatically load and unload device drivers. If all the three components - operating system, BIOS and the hardware devices and drivers support PnP, installing new devices is as easy as plugging them in and turning on the system. Hardware identification and configuration is completely automated and transparent to the user.

10.1. Plug and Play in IR devices

The IrDA protocol stack enables IR devices to communicate with each other. But communication capability alone does not imply PnP. The main focus of PnP in IR devices pertains to host and peripheral inter-operability. IrLAP communication devices are standard PnP device consuming physical resources. IR peripherals do need a mechanism for device identification.

Ease-of-use and transparency to the user are the main reasons why connecting to an IR peripheral must be logically similar to connecting to a physically attached peripheral. After the IR peripheral has been discovered and identified, the IR peripheral should appear in the host's view of the underlying hardware. Similarly when the user removes the peripheral, it should be removed from the host's view. This document only provides the high level view of issues relating to PnP IR devices and any operating system related PnP issues are beyond the scope of this paper.

For an IR device to be PnP compatible it should suffice the following condition [15]:

10.1.1. Device identification

This involves the following two processes:

10.1.1.1. Device discovery

In the IrLAP discovery process the DeviceInfo field contains a service hint mask which has a single bit field defined that when set, indicates that the responding IrDA compliant device is PnP compatible. The IrLMP layer controls the content of the DeviceInfo field. Care must be taken to handle the case in which a non PnP compatible device could set the service hint mask.

10.1.1.2. Device identification

Once the device discovery process has been completed the host must determine the capabilities of the device. The IrLMP provided information access service (IAS) to allow devices to exchange information specific about the device capabilities. These specifications add an IAS object for PnP IR devices. The IAS PnP object contains two attributes that are needed to identify the discovered IR device. These are:

- the DeviceID attribute which is the key to recognition of devices in the PnP arena
- the Category attribute which defines the specific class of function supported by the PnP IR device

11. IrDA based products in the market

IrDA has over 100 member firms most of which are leaders in the computer and telecommunication hardware, software and component sector. Companies such as HP, IBM, Sharp, Toshiba, Gateway 2000, Texas Instruments, NEC, DEC and Matsushita among others have already released notebooks and other peripherals with built-in IrDA capabilities. Many additional vendors join these major firms every month in announcing new products with the IrDA features. Microsoft Corp. announced on November 7, 1995 the added support for IrDA connectivity to the Microsoft Windows 95 operating system, making it the first operating system to be IrDA compatible.

IrDA has established a trademark licensing program designed to provide IR link interoperability across brand names based on full compliance to the IrDA standards. The products that pass the IrDA compliance requirements may use the IrDA "Beaming IR" trademark on the products or its packing as well as in advertisement related to that product.

Some of the most promising products that have been announced in the recent months with IrDA compatibility are listed as below:

11.1. Laptops

Laptops featuring IrDA-compliant IR ports are available from:

- IBM's ThinkPad 755C series
- HP's Omnibook 600 and Omnibook 4000
- DEC's models of the HiNote Ultra series
- Gateway 2000 models of the Liberty series
- Texas Instruments models of the TravelMate service

11.2. Printers and printing solutions

HP announced in March 1995 [17] the black and white **LaserJet 5P** which was the first printer to offer support for Infrared wireless communication complying with the IrDA specifications. Equipped with built-in Infrared (IR) technology, the LaserJet 5P provides users of IR-compatible computing devices to print files, at data speeds of up to 115 Kbits / s and a range of up to 3 feet, without first having to establish a physical connection between the printer and the host machine. Now it's possible to print documents in much the same way as one uses the remote control to control the TV. With street price of under $1,000 US LaserJet 5P provides proof that wireless computing can be easy and affordable.

Lexmark International Inc. raised the standards even further when they announced the **MarkNet IR** in August 1995. [18] It is a high-speed infrared device that eliminates switch boxes or cables needed for printing or transferring files between an infrared portable

computer and a desktop PC or printer. The MarkNet IR is certified by the IrDA and can transmit data at speeds of up to 1.152 Mbps to distance of more than 9 feet. The device is just four and a half inches square and a half high and weighs about a pound. It includes two high-speed, bi-directional parallel ports, an external power supply, Lexmark's MarkVision network printer management utility and Puma Technology's popular TranXit wireless file transfer technology.

11.3. Operating system

Microsoft announced [19] on November 7, 1995 that it had added support for IrDA connectivity to **Windows 95** operating system making it the first operating system to be IrDA compatible. Now Windows 95 based PC's that support IrDA connectivity can communicate with IrDA compliant peripherals and with other PC's running Windows 95 with IrDA support. Support for IrDA connectivity in Windows 95 means added convenience for mobile users of Windows 95 because it makes communication between devices easier and more flexible. IR enables users of Windows 95 to connect to peripheral devices or other Windows 95 based PC's easily, by just pointing the computer at the target device or other Windows 95 based PC's easily, by just pointing the computer at the target device and transmitting. IR also supports Plug and Play which allows Windows 95 to recognize IR peripherals and install and configure the necessary drivers automatically.

11.4. Electronic organizers

Handheld computers, personal digital assistants (PDA's) and electronic organizers compatible equipped with an IrDA compliant port are already available in the market. The one that has received the most attention is the **Sharp Zaurus**. The Zaurus Keyboard-enhanced personal digital assistant (K-PDA) is a pocket-sized, personal communication tool that offers near instantaneous access to information. This helps business executives to exchange information is real time with the staff at the office. Fax, e-mail and on-line database access capabilities make Sharp Zaurus a portable communication power-house. Equipped with the stylus pen, writing notes on Zaurus screen is as simple as using a note pad. With all these features the Zaurus is compatible with the IrDA. This means that all the information that you have on your Zaurus can be easily beamed to IrDA compatible laptops, PC's and printers and other Zaurus. The touch-screen graphical user interface is easy to understand. The applications can be easily opened by pressing icons on the 320 x 240 dot screen with the stylus pen or your finger.

11.5. Test suits and tools

In order to use the IrDA beaming IR logo, manufacturers must provide a signed statement that the IrDA compliant device has been thoroughly tested. **Genoa Technology** provides a powerful set of **test cases** and **test tools** that assure interoperability with other devices when the device is launched in the market. [20] The **Genoa SIR tester** is a small device that can quickly determine whether a computer or a peripheral is able to communicate

using the IrDA protocol via serial infrared link. The SIR tester can perform a variety of functions like the:

- Pass / fail peripheral test
- Pass / fail computer test
- Send and receive test frames
- Test the presence of IR energy
- Genoa's strategy is to provide a core set of almost 600 test cases which verify the basic functionality of the IR energy

The pass / fail LED's clearly indicate the test results.

To test the other compliant layers of the IrDA protocol stack besides the physical SIR layer Genoa Technology provides a core set of almost 600 test cases which verify the basic functionality of the IrLAP and IrLMP layers. The entire testing procedure is integrated into **Genoa's Test Job Management Systems**. It provides a friendly user interface, ability to switch between test suites, creating new test jobs and managing the entire test reporting process.

11.6. IrDA hardware adapters and protocol software

Many vendors offer ready made solutions that can be used by other companies in their products to make them IrDA compatible without investing crucial time and money to develop the technology in-house. Some of these solutions can cut the IrDA compatible hardware and software development time by as much as 90%. Some of the these solutions are listed as below:

- **Counterpoint Systems Foundr**y provides the IrDA protocol stack and the drivers for the specific IR hardware that your product has. Counterpoint licenses stacks and driver software for the full range or IrDA specifications on a variety of platforms. They however provide no hardware (IR adapter) which you have to either develop yourself or buy from a third party.

- **ACTiSYS** offers a wide variety of IrDA solutions including the IrDA protocol software, adapter hardware and testing software. [21] They offer two versions (ACT-IR220L and ACT-IR200L) of their IrDA serial adapter. They also offer IrDA printer adapter with built-in IrDA protocol firmware like the ACT-IR100M which plugs in the Centronics port of the printer.

- PHASER**IR** is a serial infrared adapter from **AMP** with speeds of up to 115.2 Kbps and distances of up to 1 meter. This provides the hardware solution only and the work developing the IrDA protocol stack is still left for the team developing the product.

- **IBM** also provides a serial infrared adapter with the speed of up to 1.152 Mbps. These adapters come with the TranXit communications software from **PUMA Technology** which is IrDA compatible. [22]

12. Infrared wireless communication and its competition

When the Infrared Data Association held its first meeting on June 28, 1993 for the purpose of establishing a ubiquitous, low-cost, point-to-point serial infrared standard the major competing technologies that existed at that time were:

- Serial Infrared (SIR) from Hewlett Packard
- ASK from Sharp Corporation
- Magic Beam from General Magic Incorporation
- FSK from Motorola

But by the time the first standard was approved by the IrDA on June 30, 1994 most of the above mentioned technologies had already lost their significance. Since all the major players including Apple Computers, Motorola, IBM, HP, Fujistu, General Magic and Siemens had jointly helped to define the protocol having individual proprietary standards did not make sense anymore. Previous experience of Apple Computers with their Apple Newton MessagePad had given a very clear indication to the market that incompatible systems could not be successful in the market place. The Apple Newton MessagePad had a built-in infrared transmitter / receiver. When it was first released communication were possible only between Newton units as the Apple infrared communication protocol was not compatible with the HP systems. Tandy and Casio had the same incompatibility problems with their Zoomer PDA - two Zoomers could "talk" to each other over infrared, but were not compatible with any other product in the market. [6] IrDA, with its charter to develop an industry-wide infrared standard for point-to-point communication, was a dream come true for the companies who were developing infrared products.

Now the closest competitor of the IrDA proposed IR standard seems to be the Radio Frequency (RF) wireless communication. Each technology has its own set of advantages and limitations.

12.1. Advantages of the IR communication over RF communication

The main points that make the IrDA proposed IR communication advantageous over the RF communication are:

- **License-free operation:** One of the main advantage over RF is that IR is not licensed anywhere in the world and therefore there is no spectrum assignments to worry about. In the Unites States, this translates to no FCC license, no fees , no auctions, and no costly equipment testing and certification. These factors significantly reduce the length of time needed for system development and the resulting production cycle [4]. These savings are then passed on to the user. Unlike the RF devices there is a genuine possibility that the same IR device could be used anywhere is the world. Vendors find this advantage the ultimate plum to design and produce one model for distribution in multiple countries.

- **Low cost implementation:** The IrDA standard was designed to utilize low cost components with implementation costs to the manufacturer only several dollars per device (between US $ 1.50 to US $ 4.50) [23]. With expected integrated chips including IrDA functionality there will be only the very low cost (less than one US dollar) of common optoelectronic components. IR receiver and transmitter elements use low cost, easily available components. Simple layouts and lack of shielding makes IR transmitters and receivers cheap to design and manufacture. No special or proprietary hardware is required. Also the saving in terms of no licenses, no fees , no auctions, and no costly equipment testing and certification reduces the overall cost of the IR devices significantly over the RF devices.

- **Better security:** IrDA communication model is designed to be easy to use and supports a conscious connectivity usage model. Directionality of the IR beam provides additional user comfort of not unintentionally "spilling" the transmitted data to nearby devices thereby making it a more secure link [6]. Therefore unlike the RF wireless communication, IR wireless communication can be confined completely to the four walls with no leakage or interference to the adjacent user [23]. IR cannot pass through the walls but bounces off them. Since RF signals can propagate through the walls, data security is at risk and therefore encryption is mandatory to avoid information leakage [24].

- **Higher data rate:** The first standard, featuring the SIR and the IrLAP protocols enable data exchange at 115 Kbps. The 115 Kbps speed is sufficient for transferring small files, but may not be satisfactory if a large amount of data and graphics needs to be transferred [6]. Although the subsequent IrDA standards have defined the SIR physical layer link protocol to operate at a higher speed of 1.115 Mbps, similar to the one that is used in the IBM ThinkPad. The protocol is inherently similar as the one used for 115 Kbps however the data transfer rate are increased by a factor of ten. The potential replacement of parallel ports and possibly Ehernet links with IR requires even higher transfers rate leading the IrDA to design a new SIR physical layer link protocol with data transfer rate of 4.0 Mbps. Although only a few manufacturers have released products designed to support 4.0 Mbps data transfer rate, the situation is likely to change in the next few months [4]. With RF speed of anywhere between 64 Kbps to 1 Mbps per channel is attainable which is less than the speed IR devices can operate[24].

- **High noise immunity:** IR offers communication free from ionosphere effects and electrical interference. Its transmission in turn does not create any interference with radio, TV or cellular reception. It does not affect the operation of computers or their peripherals [4]. IrDA-SIR physical layer link can achieve bit error rate of better than 1 in 10^9 at range of up to 1m, while still providing a high level of noise immunity within a typical office environment. Since RF signals can penetrate walls they can cause interference with the neighboring networks [24].

- **No antenna:** Unlike the RF communication the IR communication does not need any antenna.

12.2 Limitations of the IR communication over RF communication

Some of the major limitations of IR communication over RF communication are:

- **Too directional:** Directed, point-to-point connectivity of the IrDA-SIR physical layer link provides security to the users but at the same time it poses restrictions on the angular spread of the IR beam. That means the user has to align the handset device to the target to achieve an IR link. But with the IrDA-SIR physical layer link requirement for the transmitters and the receivers to have at least a half-angle of +/- 15 degrees gives users the ability to point and shoot with relative ease [23]. But it still does not solve inherent problem of having to aim the handset or portable device towards the target.

- **Line of sight:** IR being a light medium, IR communication is limited to a straight, or line of sight path and can be blocked by opaque objects [2]. It works on the same principal like the remote control of the TV or VCR which are faced with similar limitation. Also, IR transmitters and receivers are easily interrupted by moving objects, such as people.

- **Sensitivity issues of the IR photodiodes:** One of the main problem with the IR communication is that the IR photodiodes are desensitized by sunlight, limiting the sensitivity of the receiver and the effective transmission distance of the links. [4] The problem becomes really intense when the IR system is used outdoors or even near a window on a clear day where there is a lot of sunlight falling directly on the photodiode. Besides the sunlight, strong and direct fluorescent and incandescent light can also desensitize the IR receiver photodiode.

- **Less range:** The SIR physical layer link protocol's link length is from zero to at least 1 meter. With RF products the range is much higher and can be easily extended using repeaters. For example the Wireless LAN Advanced product from IBM has a range of 1600 feet (diameter) and with the optional custom cable kit the antennas can be extended another 550 feet from the wireless base.

- **Safety:** RF communication poses no known safety hazard to the users but IR systems can cause eye damage with the infrared emitting diodes (IRED). The main damage to the retina is produced by wavelengths between 0.4 and 1.4 μm (which includes both visible and near infrared). This zone is commonly known as the retinal hazard region. In this region when an object is viewed directly, the light forms an image in the fovea. The typical result of a retinal injury is a blind spot, or *scotoma*, within the irradiated area [24]. But experiments show that there are no long-term cumulative effects of near-infrared laser radiation on visual function or retinal tissue [25].

13. Conclusion - The future of IR

There will clearly be a future of IR wireless communication as long as there are people on the move. Wire and cable communications will provide the predominant share of the communication backbone infrastructure of the twenty-first century.[1] As a wire / cable replacement solution, IrDA will however continue to provide cordless convenience for mobile computer users. The IrDA ports will replace cables and floppies and give the mobile computers user cordless convenience with point and beam ease. IR may make the ultimate dream possible with a single wire connecting the computer to the outside world - the power cable.[4]

IrDA promises to be a worldwide accomplishment, with member firms representing over 100 industry leaders. Consumers in the immediate future should expect to see the IrDA logo at the back of their new laptop computer and should be able to exchange data between a wide variety of electronic devices regardless of the manufacturer of the product. Recent industry shows such as CeBIT 1995 and Comdex 1995 saw many new products implementing IR connectivity. Many additional vendors joined major firms such as AST, Compaq, DEC, Gateway 2000, HP, IBM, Matsushita, NEC, Sharp, Texas Instruments and Toshiba in announcing new laptop computers and peripherals with IrDA compatibility. IrDA standard was recognized at the Fall Comdex 1994 and by the Byte magazine as a ***"most significant technology"*** award finalist. [26]

Microsoft recent announcement of its IrDA protocol driver support within Windows 95 operating system was a big boost to the already growing acceptance of the IrDA protocol as a new industry standard.[19] IBM and Apple Computers are also expected to provide IrDA support for their operating systems. [27]

IrDA realizes the need for high speeds of data transfer to be successful against RF communication in the future. IrDA's commitment to the higher speed data transfer is evident from its announcement of the new extension of the IrDA standard publication in October 1995, which highlights 1 Mbps and 4 Mbps extensions. Both these high speed extensions are fully backward compatible to the 115 Kbps implementation. [9]

The IrCOMM protocol that is currently being finalized by IrDA will support PC serial and parallel communication port applications. In addition it will provide a framework to public telecom network and cellular phone support which will complement exciting new IrDA enabled applications. [27] IrCOMM would also truly enhance the reliability of equipment by eliminating the connector and cable uncertainty so crucial in medical situations. The idea gains further credibility considering that existing medical instrumentation hardware would need little modification with a system like IrCOMM. [4]

Applications in the near future will include synchronizing electronic phonebooks and schedules, exchanging business cards between handheld PC's, fax or e-mail directly from a laptop computer through public phone or storing bank records from ATM machines by making a simple, walk-up and point IR connection. Industrial and service data collection applications will expand dramatically utilizing mobile IrDA enabled devices to improve control, documentation and docking procedures in the workplace. The future also

promises integrated devices that access the home's entertainment, security and automation / environment systems. [26]

IrDA vendors are also working on the PDA's that will soon be able to download voice, fax and e-mail messages as text listings from intelligent voice mail systems. Sending out a product brochure or price list will be as easy as clicking on an icon. This application will be a great time and money saver for business travelers.[7] All these above mentioned applications are precisely the kind of things that drive the end user adoption.

Despite all the promising factors of the IrDA standard it still needs to address the problems of security, interference, sensitivity of the IR photodiodes, limited range and the health and safety hazards from the infrared emitting diodes (IRED's). Till all these issues are not resolved I feel that IrDA standard will not have a 100% acceptance in the market place. Also IrDA has to continuously strive to increase the speed of data transfer to keep up with the challenges from RF communication.

The potential of IrDA to come up with this new industry standard and become successful in a short span of few years makes me feel confident that they can resolve the remaining issues. The future looks really bright for IrDA and the future is w**IR**eless.

14. List of acronyms

AII	Active input interface
AOI	Active output interface
API	Application program interface
AT&T	American Telephone and Telegraph
ARDIS	Advanced radio data information service
BER	Bit error ratio
BIOS	Basic input output system
CCIT	Comité Consultatif International de Télégraphique et Téléphonique (International Telegraph and Telephone Consultative Committee)
CDMA	Code division multiple access
CDPD	Cellular digital packet data
COMM	Denotes a serial port
CRC	Cyclic redundancy check
DEC	Digital Equipment Corporation
DTR	Data transmit ready
E-mail	Electronic-mail
FCC	Federal Communications Commission
FCS	Frame check sequence
FSM	Finite state machine
FTP	File transfer protocol
GDI	Graphics device interface
GUI	Graphical user interface
HDLC	High level data link control
HP	Hewlett-Packard
IAS	Information access service

IBM	International Business Machines
ICC	IrLAP connection control
ISAP	IrLAP service access point
IR	Infrared
IrCOMM	The emulation of serial and parallel ports
IrDA	Infrared data association
IRED	Infrared emitting diodes
IrLAP	Infrared link access protocol
IrLMP	Infrared link management protocol
IrTP	Infrared Transport Protocol
Kb/s	Kilobits per second
K-PDA	Keyboard-enhanced personal digital assistant
LAN	Local area network
LCC	LSAP-connection control
LED	Light emitting diode
LM-IAS	Link management information access service
LM-MUX	Link management multiplexer
LSAP	Link service access point
Mb/s	Megabits per second
msec	Milliseconds
NMT	Narrowband modulation technique
nsec	Nanoseconds
OOS	Optical over shoot
OSI	Open system interconnection
PC	Personal computer
PCCA	Portable computer and communication association
PCS	Personal communication services

PCL	Printer command language
PDA	Personal digital assistant
PDL	Page description language
PnP	Plug and play
PS	PostScript
RF	Radio Frequency
SIP	Serial infrared interaction pulse
SIR	Serial infrared
SMR	Specialized mobile radio
SST	Spread spectrum technique
Tf	Fall time
Tiny TP	Tiny transport protocol
Tr	Rise time
TV	Television
UART	Universal asynchronous receive / transmit
µsec	Microseconds
UV	Ultraviolet
VCR	Video cassette recorder
WAN	Wide area networks

15. References

[1] Pelton J. "*Wireless and Satellite Telecommunications - The Technology, The Market and The Regulations*" 1995 Prentice Hall Inc.

[2] Schneiderman R. "*Wireless Personal Communications: The Future of Talk*" IEEE Press 1994

[3] "*Unplugged*" Wireless Communications - Networking Systems. IBM Networking Divisions, Research Triangle Park, NC. 1994

[4] Art Makosinski "Exploring IR Communications - Something to Sing About". Mobilis - a Volksware publication Vol. 1 No. 4 October 1995.

[5] NTIA / OSM - The Spectrum Defined Location:
http://www.ntia.doc.gov/osmhome/roosal.html

[6] Seybold A. M. "*Using Wireless Communications in business*" 1994

[7] Brodsky I. "*Walk-Up Data and the Infrared Revolution*" . Wireless Magazine Vol. 3 No. 6 November / December 1994.

[8] Components. WWW Location: http://www.hp.com/HP-COM/3.0/3.3.3.1.2.html

[9] Infrared Data Association: Overview.
WWW Location: http://www.irda.org/irda/standard-overview.html

[10] Infrared Data Association, "*Serial Infrared Physical Layer Link Specification*" Version 1.1a May 1995

[11] Infrared Data Association, "*Serial Infrared Link Access Protocol (IrLAP)*" Version 1.0 June 1994

[12] Infrared Data Association, "*Link Management Protocol (IrLMP)*" Version 1.0 August 1994

[13] Infrared Data Association, "*Use of ISO 8073 as an IrDA Transport Protocol*" Version 1.0 August 1994

[14] Infrared Data Association, "IrCOMM:Serial and Parallel Port Emulation over IR (Wire Replacement)" Draft Version 0.2f September, 1995

[15] Infrared Data Association "*Plug and Play extensions to the Link Management Protocol*" Version 1.0 September 30, 1994.

[16] Ta L. "Page Description Languages: The Ups, The Downs and The Potentials". RIT masters project archives, May 1995.

[17] HP Press Release - HP Introduces Low-Cost, Wireless Laser Printers.
WWW Location: http://www.hp.com:80/pressrel/lj5bw.html

[18] Release - MarkNet IR-Infrared File Transfer and Printing - PC Users.
WWW Location: http://www.lexmark.com/press/mn_ir.html

[19] Microsoft Announces IrDA Support.
WWW Location: http://www.microsoft.com/corpinfo/press/1995/95nov/irdapr.htm

[20] Serial Infrared Testing Products.
WWW Location: http://www.gentech.com/sir-over.html

[21] ACTiSYS IrDA Products Showcase.
WWW Location: http://www.cnwnet.com/~people/tonyl/actisys/product.html

[22] Serial Infrared Adapters. WWW Location:
http://www.chips.ibm.com/products/pcmcia/40014.html

[23] Eng T Tan *"IrDA Market Requirements - Basis for the IrDA Technical Standards"* Version 3.2 November 23, 1993.

[24] Santamaría A. and López-Hernández F. J. *"Wireless LAN Systems"*, 1993 Artech House, Inc.

[25] Ham W. Y., Mueller H. A., Ruffolo J. J., Guerry R. K. and Clarke A. M. *"Occular effects of GaAs lasers and near infrared radiations"*, Applied Optics, Vol. 23, No. 13 July 1984.

[26] LaRoche J. *"The Infrared Data Association (IrDA)"*. Press Release - Infrared Data Association, Walnut Creek, California, USA

[27] LaRoche J. *"Invitation to the IrDA **BeamFest**"*. Press Release - Infrared Data Association, Walnut Creek, California, USA. Invitation to attend ***"BeamFest"*** at COMDEX 95, November 13 - 15, 1995.