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11.0 Wireless Packet Systems

Objectives

This section will:

- Examine wireless piconets
 - Examine random access techniques
 - Examine wireless LANs
 - Examine national packet radio data systems
 - Consider the future of wireless data networking
-

http://www-dse.doc.ic.ac.uk/~nd/surprise_96/journal/vol4/vk5/report.html#step1
[Newbridge Wireless Network Systems](#)
[Evolution Toward Third Generation Wireless Networks by Steinbugl](#)

11.1 WPANs

Wireless Personal Area Networks are being specified by IEEE 802.15 Working Group. Perhaps the most significant part of this effort is Bluetooth.

11.1.1 Bluetooth

The Bluetooth initiative started with Ericsson. The name is derived from a 10th century Danish king who is believed to have united warring factions in Denmark and Norway.

www.bluetooth.com
[Bluetooth Specification Vol. 1](#)
[Bluetooth Specification Vol. 2](#)
[Bluetooth PC Card Transport Layer by Nokia](#)
[Bluetooth Architecture Overview by Intel](#)

Bluetooth is a very short-range radio link that will probably have a great impact on end-users and equipment design. There are three principle applications for this technology:

- Data/voice access
- Personal ad-hoc networks
- Cable replacement

The widespread deployment of Bluetooth has been delayed because of the lack of interoperability between vendors. This has happened because as of October 2000, there is no conformal testing facility to insure interoperability.

Basic Characteristics

Modulation	GFSK
Modulation Index	0.32
BT	0.5
Max Peak Deviation	175 KHz
Aggregate Bit Rate	1 Mbps (later 2 Mbps)
User Data Rate	721 Kbps (3 voice channels)
Duplex	TDD
Frequency Hop Rate	1600 hops/sec
Tx Power Level	Class 1: 0 to 20 dBm Class 2: -6 to 4 dBm Class 3: ≤ 0 dBm
Range	10 meters

Bluetooth will allow up to 8 devices to be networked into a piconet. Piconets can be connected to form scatter nets. These small, self-configuring, personal ad-hoc networks support asynchronous channels for data and synchronous channels for voice. Each unit has a unique 48bit address.

ISM Band and Carriers

Country	Band [GHz]	Carriers
Europe & North America	2.4 – 2.4835	79
Japan	2.471 – 2.497	23
Spain	2.445 – 2.475	23
France	2.4465 – 2.4835	23

The Bluetooth utilizes circuit and packet switching. A maximum of five time slots can be reserved for synchronous packets each at a different hop frequency. Voice can be conveyed in a 64 Kbps channel and use CVSD modulation. The asynchronous channel can support a 432.6 Kbps symmetric link or an asymmetric link of 721 Kbps in one direction and 57.6 Kbps in the other.

Although Bluetooth components are peer units, one unit must act as a master for the duration of the connection. The master unit controls the clock rate and hopping sequence.

Bluetooth supports point-to-point and point-to-multi-point connections.

Any device that initiates a connection automatically becomes the master. A master may initiate a channel by broadcasting a known address or by sending an inquiry. An inquiry is used to locate shared resources such as printers and fax machines.

The master unit sends identical page messages on 16 different hop frequencies. If there is no response, the master uses the remaining 16 hop frequencies.

Bluetooth supports SCO[†] and ACL[†] links simultaneously. The SCO links are symmetrical and send voice packets at fixed intervals. The ACL link supports symmetric and asymmetric traffic. The master unit controls the bandwidth and symmetry.

There are three error-correction schemes to reduce retransmissions:

1/3 rate FEC[†]

2/3 rate FEC

ARQ[†] for data.

Applications requiring authentication use encryption with secret key lengths of 0, 40, or 64 bits.

The typical broadcast power level is limited to 100 mW. Spectral spreading is performed by making 1600 hops per second on 79 carrier frequencies between 2.402 and 2.480 GHz. The nominal range is 10 meters, but can be extended to 100 meters by increasing the transmit power.

11.1.2 Home RF

[Technical Summary of the SWAP Specifications](#)

[Home RF Slide Show](#)

[Home Networking by Feng](#)

11.2 CSMA/CD Access

This is a form of random access. It is used as the foundation of Ethernet and is used on many wireless data networks.

11.2.1 ALOHA

ALOHA is Hawaiian for hello and good-bye.

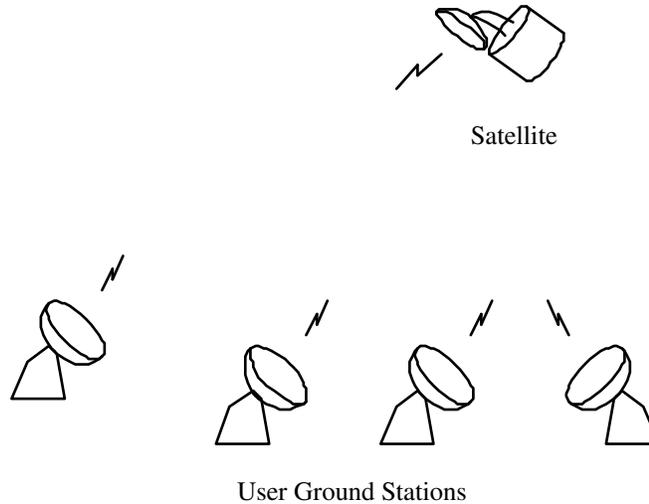
This type of communications system has great appeal because of its inherent simplicity since it has neither a switch nor controller. There are several versions of ALOHA, each with certain advantages. It is often implemented over a satellite link but it can be used on any radio facility.

[†] Synchronous Connection Oriented

[†] Asynchronous Connectionless

[†] Forward Error Correction

[†] Automatic Repeat Request



User ground stations can transmit data packets to the satellite at any time. The satellite acts as a repeater and broadcasts the packet to all users. To ensure some sort of privacy, the users must provide their own encryption. It is possible however, that two or more users may attempt to transmit up to the satellite at the same time. This condition is called a collision since the data packets involved will be damaged.

To determine whether a collision has occurred, the user initiating the transaction listens to the rebroadcast signal and compares it with the original. If the packet has been corrupted, a collision is assumed to have occurred. Stations attempting to broadcast then back off for a random time and attempt a retransmission. ALOHA systems come in a number of variations, each attempting to increase the overall throughput by minimizing collisions.

Simple ALOHA Characteristics

In order to simplify the analysis, the following assumptions are made:

- All packets are of constant length
- No channel noise [i.e. the error rate is not noise dependent]
- Each station can transmit its packet before the next one arrives
- The incoming request for service follow a Poisson distribution.

Definitions:

S network throughput. This expresses how much data the network is actually carrying. It is usually normalized [designated by s] and expressed as a fraction of network capacity.

G total data rate presented to the network. This is also generally normalized [designated by g].

I total data rate generated by the nodes.

D average delay

The users are independent from each other but share a common uplink resource. Data collisions can occur in the uplink. The total traffic on a channel [G] is given by:

$$G = S + R_t$$

Where S = number of new packets arriving

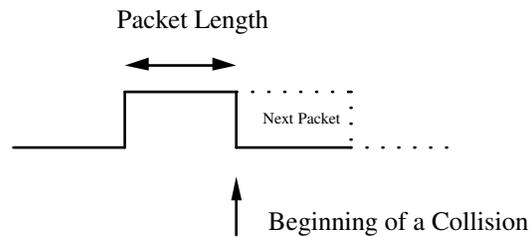
R_t = number of retransmitted packets due to collisions

The number of retransmissions [R_t] is:

$$R_t = G \times PoC$$

Where PoC = probability of collision.

The collision vulnerability period is twice the packet length.



If packets arrive with a Poisson distribution at an average rate of λ , the probability of collision (PoC) in a given period of time [t] is:

$$PoC = 1 - e^{-\lambda t}$$

Therefore the probability of colliding during a 2-packet length period is:

$$PoC = 1 - e^{-2G}$$

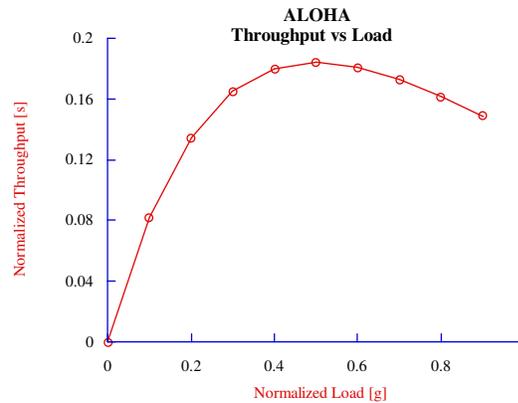
Making the appropriate substitutions, we can express the total traffic [G] as:

$$G = S + G(1 - e^{-2G})$$

Solving for throughput (S):

$$S = Ge^{-2G}$$

A normalized plot of this function [with load varying between 0 and 1] is:



As can be seen from the graph, the throughput rises to a maximum and then falls off. To find the maximum possible throughput, differentiate the equation with respect to G and set the result equal to zero:

$$\frac{dS}{dG} = e^{-2G} - 2e^{-2G} \quad \text{Therefore} \quad 0 = 1 - 2G$$

In normalized units the maximum system load is, $g = 0.5$. Substituting back into the original equation, we find that the maximum throughput is, $s = 0.18$.

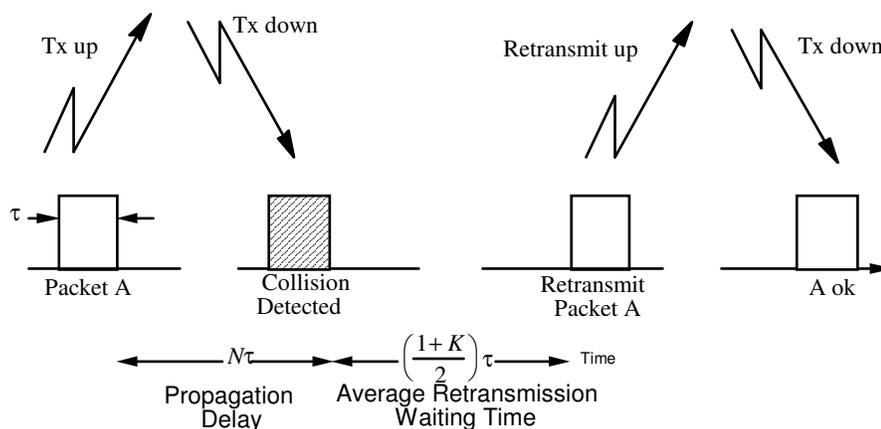
Therefore at maximum throughput:

- The system is running at 1/2 maximum capacity.
- The actual useful throughput is only 18% of the theoretical maximum
- And the average packet is transmitted $g/s = 0.5/0.18 = 2.78$ times.

Delay Characteristics

Inevitably collisions will occur, forcing a retransmission and creating an inevitable delay. The delay will increase as system load increases since the probability of will collisions increase.

ALOHA Delay Characteristics



Where: τ = packet length

$N\tau$ = propagation time up and down to satellite as a multiple of the packet length

If a collision is detected, a random waiting period of 0 to K packet lengths is invoked before retransmission is attempted. Therefore the average waiting time is: $AWT = \frac{(1+K)\tau}{2}$

This process is repeated G/S times since traffic/throughput represents the average number of times each packet has to be retransmitted before being successfully delivered. The total average delay is then:

$$TAD = \tau + \left[N\tau + \frac{(1+K)\tau}{2} \right] \frac{G}{S} - \frac{(1+K)\tau}{2}$$

The last term removes the average random waiting time on the last transmission since it was successfully received.

Another expression for TAD is:

$$TAD = \frac{\tau}{2} \left[1 + e^{2g}(1 + 2N) + K(e^{2g} - 1) \right]$$

Example:

An ALOHA channel has a maximum capacity of 50 Kbps. If the average packet length is 20 mSec, the propagation delay is 250 mSec, and $K = 10$, find G , S , TAD , and the number of times the average packet is transmitted before being successfully received, if the system is running at maximum throughput.

Solution:

For a simple ALOHA system, the capacity peaks at $g = 0.5$.

Therefore the maximum load is: $G = 0.5 \times 50 \text{ Kbps} = 25 \text{ Kbps}$

The throughput also peaked at $s = 0.184$.

Therefore the maximum throughput is:

$$S = 0.184 \times 50 \text{ Kbps} = 9.2 \text{ Kbps}$$

The propagation delay in terms of packet lengths is:

$$N = \frac{250 \text{ mSec}}{20 \text{ mSec}} = 12.5 \text{ packets}$$

$$TAD = \frac{0.02}{2} \left[1 + e^{2 \times 0.5} (1 + 2 \times 12.5) + 10(e^{2 \times 0.5} - 1) \right] = 0.89 \text{ Sec}$$

Average number of times a packet is transmitted before being successfully received:

$$\frac{g}{s} = \frac{0.5}{0.184} = 2.72$$

This may seem to be an inefficient system, but it does have some significant advantages:

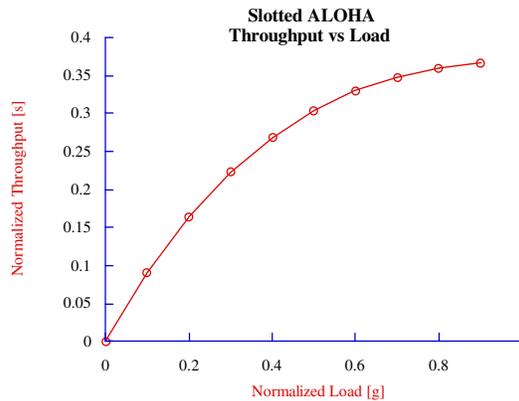
- Simple allocation protocol
- Overall average delay is small (typically < 1 sec.)
- No channel capacity is dedicated to inactive users

11.2.2 Slotted ALOHA

By establishing fixed time slots, the vulnerability period can be cut in half since packets will entirely collide or not at all. This is accomplished by having the satellite transmit a clock, and ground stations transmit only at the beginning of a time slot, thus preventing partial collisions.

The disadvantages of this system is that the ground stations become potentially complex, as they now must synchronize to the satellite and compensate for its range, which controls the propagation time delay. This also means resources are wasted if the packet is smaller than the time slot.

The throughput for this system is given by: $s = ge^{-g}$



At peak capacity, slotted ALOHA can double the channel throughput with a slight increase in average delay. At it peak, the average packet would have to be transmitted g/s or $1/0.37 = 2.7$ times before being successfully received.

$$TAD = \tau(e^g - 1) \left[\left(1 + 2N + \frac{K+1}{2} \right) + 1.5(N+1) \right]$$

Example:

An S-ALOHA channel has all the characteristics of the previous example. Find G , S , TAD , and g/s , if the system is running at maximum throughput.

Solution:

$$G = 1 \times 50 \text{ Kbps} = 50 \text{ Kbps}$$

$$S = 0.368 \times 50 \text{ Kbps} = 18.4 \text{ Kbps}$$

$$TAD = 1.49 \text{ Sec.}$$

$$g/s = 2.72$$

11.2.2.1 CSMA - Carrier Sense Multiple Access

This is a listen before talk approach, where the station wishing to transmit only does so when the medium is idle. In order to obtain any benefit, the packet time length must be greater than the propagation delay.

In I-persistent CSMA a user monitoring the channel attempts to transmit immediately when the channel is free. The I stands for immediacy. It is also called 1-persistent CSMA, because the transmission probability is 1. Since collisions occur when two stations transmit simultaneously, and both are equally persistent, the system may go into deadlock. Because of the long transmission delays, this approach does not work on satellite links.

One way to avoid dead lock this is to wait a random time before attempting to transmit. This is known as non-persistent CSMA.

P-persistent CSMA is used in slotted ALOHA networks. It monitors the channel and sets a timer to some random value with an average value $[p]$, which is some fraction of the channel width. If $p = 0$ the stations transmit as soon as the channel is clear, and if $p = 1$, the stations transmit after a one frame time-out. The problem is to determine the optimum value for p .

If there are n stations, then the number of stations wishing to transmit is np . If $np > 1$ then collisions occur more frequently and the system will eventually clog up. If $np < 1$, the stations wait longer before attempting retransmission, therefore reducing collisions, but increasing the average delay.

Throughput can be increased by modifying the basic frame structure. Each of the following variations increased the complexity and cost of the end-user station:

Reservation

- A frame structure is imposed on a slotted ALOHA channel
- The frame length exceeds the satellite round trip delay
- Each frame is synchronized by a preamble generated by the satellite or a master ground station
- Each packet slot is numbered
- A user wishing to transmit, selects a packet slot which was unused in the last frame

Borrowed Slots

- A slot within each frame is assigned to a user
- Users may transmit in any other slot if it has been empty for one frame
- When the rightful owner wishes to use the slot, a transmission is initiated, resulting in a collision
- The borrower, detecting the collision abandons the slot

Subdividing Channels

- A master frame is divided into sub-frames
- The first sub-frame is used to make reservations by identifying the slot number and number of frames to be transmitted
- All other users keep track of each other's reservation requests

Summary of ALOHA and CSMA Throughput¹

Pure ALOHA $s = ge^{-2g}$

slotted ALOHA $s = ge^{-g}$

unslotted 1 - persistent CSMA $s = \frac{g \left[1 + g + ag \left(1 + g + \frac{ag}{2} \right) \right] e^{-g(1+2a)}}{g(1+2a) - (1 - e^{-ag}) + (1 + ag)e^{-g(1+a)}}$

slotted 1 - persistent CSMA $s = \frac{g \left[1 + a - e^{-ag} \right] e^{-g(1+a)}}{(1+a)(1 - e^{-ag}) + ae^{-g(1+a)}}$

unslotted nonpersistent CSMA $s = \frac{ge^{-ag}}{g(1+2a) + e^{-ag}}$

slotted nonpersistent CSMA $s = \frac{age^{-ag}}{1 - e^{-ag} + a}$

11.3 Wireless LANs

<http://www.netplan.dk/netplan/wireless.htm>

11.3.1 IEEE 802.11

[Brief Tutorial on IEEE 802.11 Wireless LANs](#)

[Technical Tutorial on the IEEE 802.11 Protocol by BreezeCom](#)

Frequency Band [MHz]	North America/Europe: 2400-2483 Japan: 2470-2499
Access Method	CSMA
Duplex Method	TDD
Number of Channels	FHSS: 79 DSSS: 7
Channel Spacing	FHSS: 1MHz DSSS: 11 MHz
Modulation:	FHSS: GFSK (0.5 Gaussian Filter) DSSS: DBPSK (1/MB/s) DQPSK (2 MB/s)
Channel Bit Rate	1 or 2 Mbps

Frequency (MHz):

(North America/Europe) 2400-2483

(Japan) 2470-2499

Multiple Access Method: CSMA

Duplex Method: TDD

¹ Wireless Information Networks, Kaveh Pahlavan & Allen H. Levesque, Table 11.1

Number of Channels: FHSS: 79, DSSS: 7
Channel Spacing: FHSS: 1MHz, DSSS: 11 MHz
Modulation: FHSS: GFSK (0.5 Gaussian Filter), DSSS: DBPSK (1/MB/s), DQPSK (2 MB/s)
Channel Bit Rate: 1 or 2 Mbps

This approach has the possibility of eliminating the large wiring harnesses currently being deployed in large buildings. This would reduce costs, while offering increased flexibility to the end-user. There are however, some serious concerns that may prevent the universal adoption of wireless. Some issues yet to be completely addressed include:

- Reallocation of the radio spectrum
- Interference
- Security
- Long-term health risks

The main competitor to in-building wireless will probably be fiber optics, which has none of the above concerns. In spite of this, Motorola is developing an 18 GHz microwave LAN that will initially offer a 15 Mbps bandwidth, and may expand eventually to 100 Mbps.² The coverage diameter is reported to be a maximum of 35 miles.

The IEEE has recently announced that it is developing P802.11g to enhance the bit rate of 2.4 GHz LANS from 11 Mbps to 20 Mbps.

<http://standards.ieee.org/>

11.3.0 W-OFDM

Orthogonal frequency division multiplexing.

[W-OFM Modulation by WiLAN](#)

[Technical Details of WODM by WiLAN](#)

<http://www.ofdm-forum.com/content/page1.html>

<http://www.wi-lan.com/ofdm/first.html>

<http://spacecom.grc.nasa.gov/technologies/digital/odfm.asp>

<http://pcsrv1.comm.uni-bremen.de/pub/mcarrier/index.html>

11.4 Wireless Data WANs

[A Survey of Mobile Data Networks by A. K. Salkintzis](#)

[Wireless LANs – Roaming, by DEC](#)

[Wireless Data Communications, by DEC](#)

[Wireless Data Market](#)

² *Wireless Communications: The Next Wave*, Telecommunications, December 1990

Wireless Application Protocol

There are a number of systems providing these types of services³.

System	Comments
ARDIS	Data only. Available in 400 cities.
CDPD	Cellular Digital Packet Data (WAN) Uses the existing cellular radio facilities & can provide cell site vehicle location.
CoveragePLUS	Provides approximately 20 channels, 4800 bps, mobile data and voice in most areas. Uses satellite facilities & can provide vehicle location via LORAN C.
Digital Radio Networks	Provides only 1 channel, 5 Kbps, fixed data only. Available in 65 cities.
Mobitex	Fixed or mobile data only. Uses packet switching techniques to increase capacity. First developed in Europe, where it also carries voice. It can now be found in about 100 North American cities

Many of these systems use the existing cellular telephone networks, which can be supplemented by microcellular equipment. In-building fiber or fiber to the curb, coupled to ONUs with wireless access, create microcellular environments. Wireless applications and issues are being widely examined.⁴

The principal control access technique for radio data systems is some form of ALOHA or CSMA/CD.

11.4.1 CDPD

<http://cdpd.org/cdpd/>

The CDPD[†] radio packet system is an overlay on the AMPS cellular phone system and is supported by IBM and 8 of the largest cellular carriers in the US⁵. It is currently available in more than 3000 American cities.

Frequency Band [MHz]	Rx: 869-894 Tx: 824-849
Access Method	FDMA
Duplex Method	FDD
Number of Channels	832 (4 users/channel)
Channel Spacing	30 KHz
Modulation:	GMSK (0.5 Gaussian Filter)
Channel Bit Rate	19.2 Kbps

³ *Wireless MANs/WANs Offer "Data to Go"*, Business Communications Review, February 1991

⁴ *Enabling Technologies for Wireless In-Building Network Communications – Four Technical Challenges, Four Solutions*, IEEE Communications Magazine, April 1991

[†] Cellular Digital Packet Data

⁵ *Wireless Information Networks*, Kaveh Pahlavan & Allen Levesque, Wiley, 1995

It uses CSMA over unused voice channels. The data connection is switched to another channel when the current channel is needed to make a voice connection. It also uses the IP protocol suite.

Applications include e-mail, Internet/intranet access, POS credit card authorization, ATM machines, AVL, sales force automation, dispatch for field service, taxi and law enforcement, remote alarm monitoring, telemetry, or any other application that requires remote access to a data network or database.

The CDPD basestation [MDBS] is attached to the telco's cellular radio transmitter to facilitate channel sharing. The MDBS is connected to a switching center known as an intermediate system [MD-IS]. The MD-IS connection can be established either by a dedicated microwave link or through the telco.

Each data channel is 30 KHz wide and can support a bit rate of 19.2 Kbps. However, the end-user will receive 12-14 Kbps because of the error detection and flow control algorithms. The RF modulation scheme is GMSK.

Data in the forward channel, to the mobile user [M-ES], is encapsulated into HDLC frames. It is then segmented into 273 bit long blocks. 8 bits for MDBS and MD-IS identification is added. The block is then expanded to 378 bits by a Reed-Solomon coding and by adding synchronization bits.

Data in the reverse channel, to the MDBS, is similarly formatted except that several M-ES can share the same channel. Access is made possible by DSMA/CD, which is the digital equivalent of CSMA/CD.

CSCCP

The Circuit Switched CDPD Control Protocol provides is the management of the circuit switched connection. This includes the establishment of the connection, the efficient reconnection of the session, and the detection and recovery of transmission errors. The messages of CSCCP include the following:

- Connection Request — This message is used by the CM-ES to request the establishment of a circuit switched connection with the CMD-IS. The CM-ES provides information about its own identity, cellular System ID, and callback dial code.
- Connection Response — The Connection Response is the network's response to the connection request. The CMD-IS provides its identity used for reconnection. It may also include a redirection directive and an alternative dial code.
- Reconnection Request — The CM-ES and the CMD-IS uses this message to re-establish a circuit switched connection to an active session.
- Reconnection Response — This message is the response to the Reconnection Request.
- SNDCP Data packet — This is the CSCCP message that carries the Subnetwork Dependent Convergence Protocol data packet information.

- SNDCP Unitdata packet — This is the CSCCP message that carries the Subnetwork Dependent Convergence Protocol unitdata packet information.
- Link Reset — An endpoint of the CSCCP layer uses this message to indicate a reception error and to initiate error recovery.
- Link Reset — Acknowledge This is the CSCCP message to ensure synchronization of error recovery procedures.

11.4.2 RAM - Mobitex

The Mobitex system has been implemented in Europe and North America. The North American version however, does not carry voice. This system is more hierarchical than that of Ardis.

Frequency Band [MHz]	North America: Rx: 935-941 Tx: 896-902 Europe/Asia: 403-470
Access Method	TDMA/FDM
Duplex Method	FDD
Number of Channels	480
Channel Spacing	12.5 KHz
Modulation:	0.5 GMSK
Channel Bit Rate	8 Kbps

The overall network consists of 5 layers: NCC[†], national switches, regional switches, local switches, and base stations. At the moment there are about 800 base stations in the US. The distributed switching structure allows two end-users in the same service area to contact each other without having to route all the way to the NCC.

Mobitex operates in a similar way as the cellular telephone system except that hand-offs are managed by the mobile user instead of the network. As the mobile user enters a new service area, the mobile terminal registers with the nearest base station. This allows the network to support roaming and gives it store-and-forward capability.

The mobile station transmits in the 896 - 901 MHz band and receives in the 935 - 940 MHz band. Each channel has a bandwidth of 12.5 KHz and supports 8 Kbps half-duplex data. The modulation scheme is GMSK, and the access method is dynamic slotted ALOHA.

11.4.3 Ardis-RD-LAP

ARDIS[†] is the result of corroboration between Motorola and IBM, and provides both mobile and in-building coverage in more than 400 US cities. Although it does not support voice, allows customers to communicate via RF data packets to truck fleets. Its two-way file transfers size is usually less than 10 K bytes. The base stations transmit 40 watts, providing a coverage radius of 10 to 15 miles.

[†] Network Control Center

[†] Advanced Radio Data Information Service

Frequency Band [MHz]	Rx: 851-869 Tx: 806-824
Access Method	TDMA/FDM
Duplex Method	FDD
Number of Channels	720
Channel Spacing	25 KHz
Modulation:	FSK (2 and 4 level)
Channel Bit Rate	19.2 Kbps

Host controllers are located in: New York, Lexington, Chicago, and Los Angeles. There are approximately 32 network controllers, and 1250 base stations. The network backbone is implemented on leased telephone lines.

The FDMA RF links operate in the 800 MHz band, have a bandwidth of 25 KHz and a duplex spacing of 45 MHz. The link supports 19.2 Kbps, of which 8 Kbps is for the customer and the balance is overhead. It supports X.25, SNA, async, or bisync.

The portable units use DSMA[†] access which is very similar to CSMA/CD except that it is sensing the state of a busy bit originating from the base station.

11.5 HIPERLAN

<http://www.hiperlan.com/>

<http://donald2.inria.fr/hiperlan/hiperlan.html>

<http://www.symbionics.co.uk/services/technology/HiperLAN/HiperLAN.htm>

<http://www.etsi.org/tm/access.htm>

<http://www.hiperlan2.com/web/>

[HiperLan Technology Overview](#)

[HyperLan Overview](#)

[HiperLan Slide Show](#)

[HiperLan2 by M. Johsson](#)

UMTS offers moderate data rates and high mobility while, HIPERLAN[†], WLAN and MBS support the high data rates at the expense of mobility mobility.

The ETSI has been developing HIPERLAN, the next generation of high-speed wireless system in the 5 GHz and 17 GHz.

HIPERLAN Type 1 provides bit rates of 24 Mbps in the 5 GHz band. At present, there are four members in the family.

[†] Data Sense Multiple Access

[†] HIgh PERformance LAN

HIPERLAN Type	1	2	3	4
Link Type	Wireless LAN	Wireless ATM	Remote wireless	High speed
Frequency [GHz]	5	5	5	17
Data Rate [Mbps]	>20	>20	>20	155

HIPERLAN Type 2 is currently under development in the ACTS project WAND and supports wireless ATM. <http://www.tik.ee.ethz.ch/~wand>

Comparison between HIPERLAN and MBS[†]

Parameter	HIPERLAN	MBS
Operators	Private system, owned and operated by the user	Public and private systems
Objective	Extension or replacement of fixed LANs	Mobile and wireless extension or replacement of fixed B-ISDN
Applications	Primarily indoors	Indoor and outdoor, all IBC services and applications
Services and data rates	MAC layer service rates < 20 Mbps for asynchronous services, and n x 64 Kbps for time-bounded services	ATM cell transfer capability up to 155 Mbps
Protocol	Connectionless	Connectionless and connection-oriented
Mobility	Up to 36 kph	Up to 50 kph
Coverage	Unlimited locally, through use of active forwarding nodes	Unlimited due to cellular structure and handover protocol
Range	Up to 50m at 20 Mbps	Up to 1 km depending on antenna and frequency
Channel Access	FDMA/TDMA, variable data packets up to 24 Mbps	FDMA/TDMA frame structure with fixed time slots
Frequency bands (GHz)	5.15 - 5.30, 17.1 - 17.3	39.5 - 40.5, 42.5 - 43.5, 62 - 63, 65 - 66
Physical channel rate	23.5 Mbps	40 - 60 Mbps
Modulation	GMSK	4 and 16 OQAM
Availability	1997-98	2010

There are a number of other Wireless-ATM projects under development:

AWACS - see <http://www.cselt.stet.it/sonah/AWACS>

SAMBA - see <http://hostris.cet.pt/samba/index.htm>

WAND - see <http://www.tik.ee.ethz.ch/~wand>

MEDIAN - see <http://entnw2.et.tu-dresden.de/median.html>

[†] Mobile Broadband Systems

11.6 MBS

<http://www.comnets.rwth-aachen.de/project/mbs/>

<http://www.infowin.org/ACTS/IENM/BULLETIN/06-1997/mbs.htm>

MBS and the related systems of W-LAN are extensions of the wired B-ISDN network. MBS provides radio coverage restricted to pico-cells and supports communication between MBS terminals and the B-ISDN at up to 155 Mbps.

Some of the services under development include:

- Mobile broadband applications

- Video distribution

- Interactive video

- Audio and data communications services

- ATM capability between fixed and mobile terminals

- Mobility management functions (especially for handover)

- Signaling, control and service provision protocols

- Validation of Quality-of-Service parameters

These applications are suitable for offices, financial services, medical systems, education/training and other service sectors.

The MBS will also include the use of satellites.

SAMBA

<http://hostria.cet.pt/samba/index.htm>

<http://www.infowin.org/ACTS/RUS/PROJECTS/ac204.htm>

SAMBA is developing an MBS platform consisting of a base station and two mobile terminals, operating in the 40 GHz band. The data throughput is expected to be 34 Mbps. It will support multimedia services and integrate MBS into a fixed ATM broadband network.

MEDIAN

<http://entnw2.et.tu-dresden.de/median.html>

MEDIAN will implement a high-speed W-LAN for multimedia applications. The pilot system relies on a multiple carrier modulation scheme that adapts to the channel characteristics and data rate. The system uses a 155 Mbps link in the 60 GHz band and can be connected to Third Generation mobile systems using ATM.

WAND

<http://www.tik.ee.ethz.ch/~wand>

WAND will provide ATM connections for fixed and quasi-mobile users in the 5 GHz band.. The data rate will be in excess of 20 Mbps, and the service levels will be comparable to conventional wired ATM networks.

11.7 U-NII

<http://www.winlab.rutgers.edu/~sinhar/unii.html>

<http://www.ntia.doc.gov/ntiahome/press/011097unii.htm>

U-NII stands for the Unlicensed National Information Infrastructure. The FCC has made available 300 MHz of spectrum for the U-NII devices that will provide short-range, high-speed wireless digital communications. These new devices, which do not require licensing, will support the creation of new wireless LANs and facilitate access to the information highway. The U-NII spectrum is located at 5.15-5.35 GHz and 5.725-5.825 GHz.

Assignment Questions

Quick Quiz

1. Bluetooth can handle data transactions but not voice. [True, False]
2. Bluetooth uses [FDD, TDD] to support full duplex operation.
3. A Bluetooth piconet can consist of a maximum of [4, 8, 16] devices.
4. Bluetooth [supports, does not support] asymmetrical links.
5. Bluetooth uses DS-SS. [True, False]
6. ALOHA channels are rarely used today. [True, False]
7. The maximum throughput of a pure-ALOHA system is [18, 36, 64]%.
The maximum throughput of a pure-ALOHA system is 18%.
8. The average packet on a pure-ALOHA system is transmitted nearly 3 times before it is successfully received, if the system is operating at maximum throughput. [True, False]
The average number of transmissions per packet is 2.
9. In a slotted-ALOHA system, the number of retransmissions at maximum throughput is half that of the pure-ALOHA system. [True, False]
The number of retransmissions is the same.
10. I-persistent CSMA is well suited for satellite links. [True, False]

Composition Questions

- 1.
- 2.
- 3.
- 4.

For Further Research

CDPD: www.isoel.com/cscdpd.htm

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Cawthorne, N. S.; "Countdown to Cellular Radio", Electronics & Wireless World, January 1985

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Stern Marc, "Cellular Mobile Telephones", Radio-Electronics, April 1985

Thorn, Peter; "Data Transmission on the Move", CEE, May 1986

Lee, William C. Y.; *Mobile Communications Design Fundamentals*

Mixed-Signal Design Seminar, Analog Devices, 1991

"On the World's Wavelength," Telesis, 1987 two

"Terrain Data Base Sees Both Forest And Leaves", Electronics Week, January 1985

IEEE Communications, January 1995, a special issue on Wireless Personal Communications

<http://www.wavelan.com/>

<http://www.atiradio.com/index.htm>

<http://www.wlana.com/intro/index.html>

ACTS Median <http://www.imst.de/median/median.html>

Mobile Communications On Line

<http://www.infowin.org/ACTS/ANALYSYS/PRODUCTS/THEMATIC/MOBILE/index.html>

www.bluetooth.com

<http://sss-mag.com/index.html>

Useful Links

<http://www.vtt.fi/tte/tte22/lucenius/epri/nwkinfr.html>