

HomeRF and Bluetooth: A Wireless Data Communications Revolution in the Making

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Outline

- Disclaimer
- Perspective
- HomeRF™
 - Mission, Vision, Usage, Technology
- Bluetooth
 - Mission, Vision, Usage, Technology
- Comparisons
 - 802.11, HomeRF, Bluetooth, IrDA & HIPERLAN
- Conclusions
- References

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Why is wireless data networking not ubiquitous today?

- Lack of horizontal market focus (infrastructure build-up has been slow)
- Battery life has been a big problem
- Standards have not kept pace with the Internet
- Ease-of-use factors have been poor - configuration, maintenance, and manageability has been difficult
- Lack of seamless communications between different standards
- Security has been an second class citizen
- The case for value .vs. cost is unclear
 - Wireless PCMCIA adapters cost \$500-\$700, Access points cost \$1200-1800. 10/100 Ethernet adapters cost \$150
 - Gross mismatch between cost and speed

Wireless Communications Architectural Trends

PRESENT



FUTURE

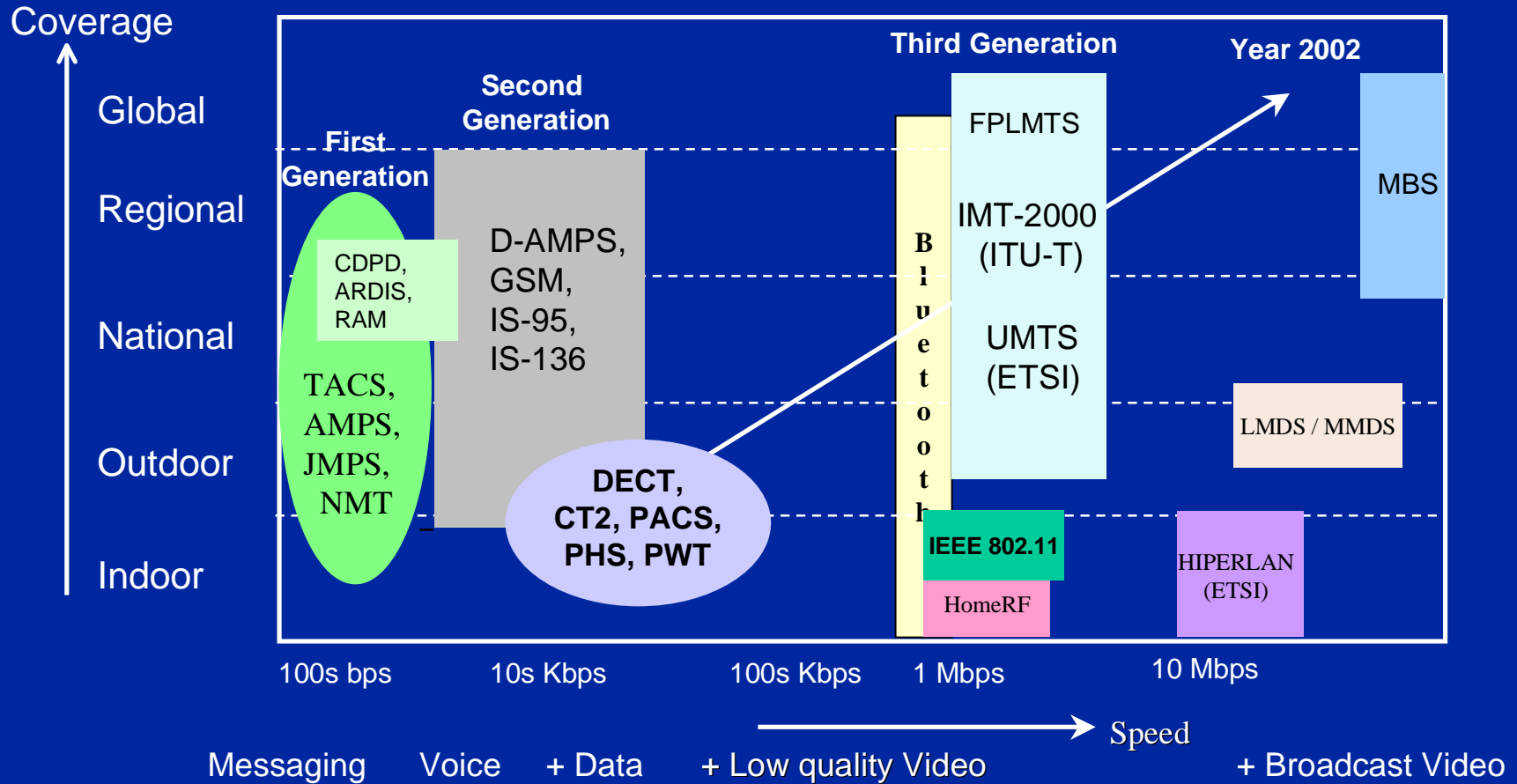
- Mostly homogeneous traffic - voice (circuit switched), data (packet switched)
- Limited coverage
- Custom wireless network API
- Vertical protocol stack built on radio air interface
- Low usage per subscribers
- Low bit-rates
- Poor cost / performance ratio
- Insecure
- Single hop networks

- Mostly heterogeneous traffic -- voice + data + video, (packet switched)
- Ubiquitous
- Generic network API
- Fixed network protocols with radio and mobile plug-ins
- High usage
- High bit-rates
- Mass market cost/performance
- Secure
- Multi-hop self configuring networks

Brief History of (some) RF Standards

- **802.11**
 - IEEE standard for the enterprise market
 - work began 1992, Final standard published 1995
 - 2.4 GHz, 2 Mbps, 50 m, CSMA/CA, DCF and PCF
- **HIPERLAN**
 - ETSI BRAN (formally RES10) RF standard
 - work began early 1992, Final standard published late 1995
 - 5.15 GHz and 17.1 GHz, 23.5 Mbps, 50 m, EY-NPMA
- **HomeRF™**
 - RF standard for tetherless home networking. 5 core members (Intel, HP, Microsoft, Compaq, IBM) + 63 member companies (pay \$\$ to become members) (as of 12/8/98)
 - official launch in March 1998, Final standard (v1.0) expected early 1999
- **Bluetooth**
 - RF standard for the business user. 5 core members (Ericsson, Nokia, Toshiba, Intel, IBM, Intel), 278 member companies (membership is free) (as of 12/8/98)
 - official launch in February 1998, Final standard expected 1999

Past, Current, and Future



Outline

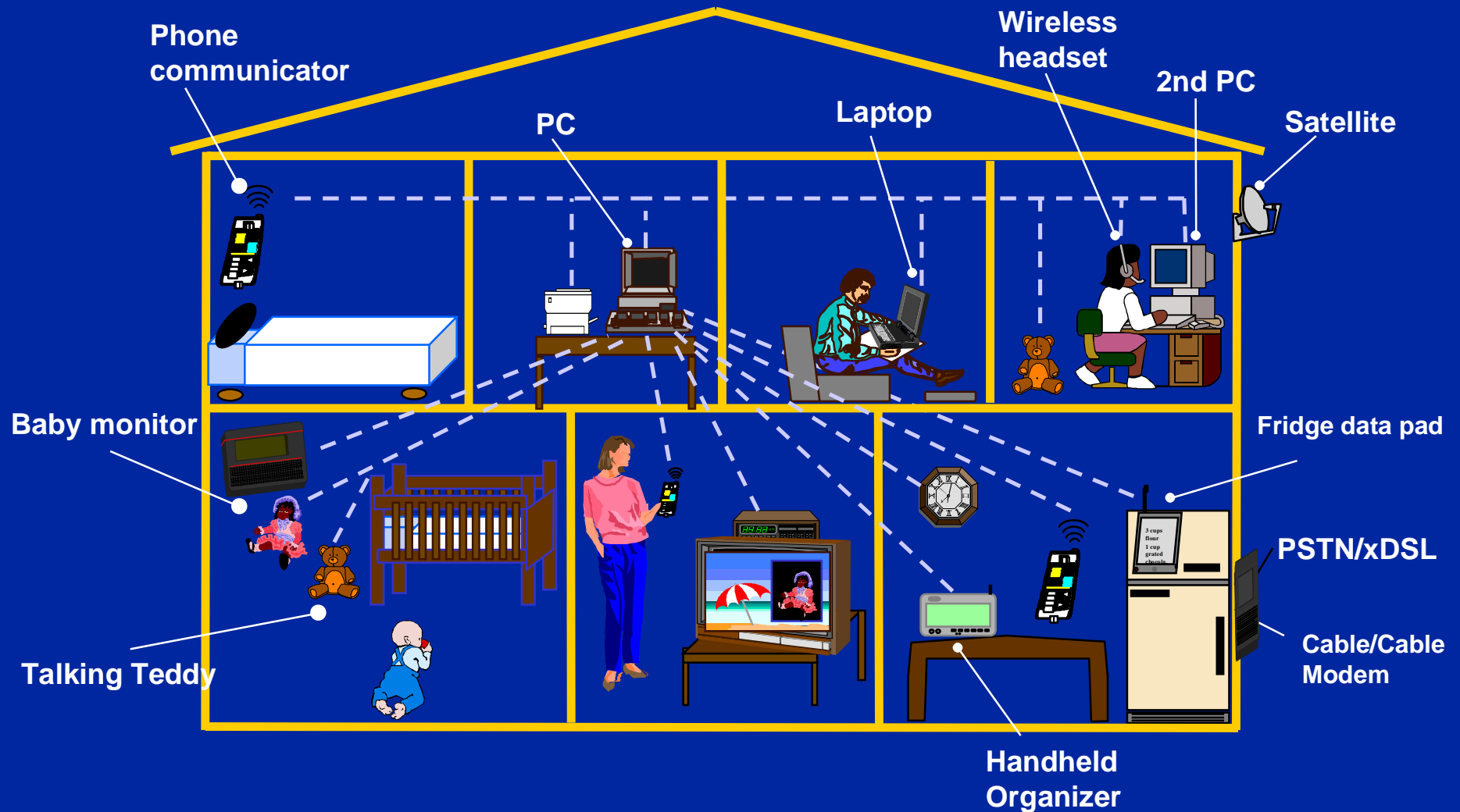
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HomeRF™ - Mission Statement

“To enable the existence of a broad range of interoperable consumer devices, by establishing an open industry specification for unlicensed RF digital communications for PCs and consumer devices anywhere, in and around the home.”



HomeRF™ - Vision



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February 11, 1999

HomeRF™ - Assumptions

- Roaming is not a concern, coverage in and around the house is sufficient.
- 2 Mbps bandwidth is (initially) sufficient for most tasks within the home.
- Simultaneous support for voice and data is desirable.
- Internet connectivity is necessary, PSTN connectivity is also necessary.
- Processing horse power for simple tasks is available.
- Tight Integration of hardware/software is necessary.

HomeRF™ - Design Goals

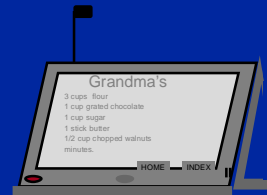
- + Operational Spectrum -- 2.4 GHz (world wide availability)
- + Data rates
 - + Standard - 1 Mbps with support for Isochronous + asynchronous traffic
 - + Optional - 2 Mbps (4FSK)
- + Range -- 50 m (short, mostly indoor, cover entire house and yard)
- + Nominal 100 mW transmit power; Minimum receiver sensitivity -76 dBm
- + Mobility < 10 m/sec (low)
- + Packet based Communications Topology
 - without infra-structure (ad hoc, peer-to-peer), and
 - with infra-structure (centralized, mobile to base-station)
- + Simultaneous support for isochronous and asynchronous traffic
 - 6 audio connections @ 32 Kbps, with < 20 msec latency (ADPCM)
 - Max data throughput 1.2 Mbps (4FSK)
- + Low power paging mode
- + Guaranteed QoS to voice-only devices, best effort for data-only devices

HomeRF™ - Device Types



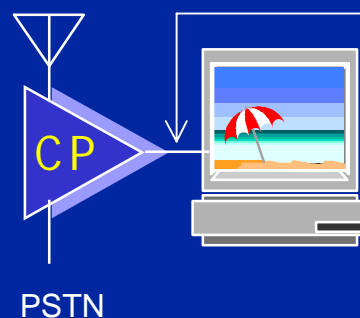
Cordless Telephone

**Isochronous access
(I node) - Voice-only device
channel access - TDMA
Connect to PC and/or PSTN**



Pad

**Asynchronous access
(A-node) - Data only devices
channel access - CSMA/CA
Networking - TCP/IP**



USB, PCI, PC-Card, Device Bay, etc.

**Connection Point (CP)
Manage a network OR act as an A-node**

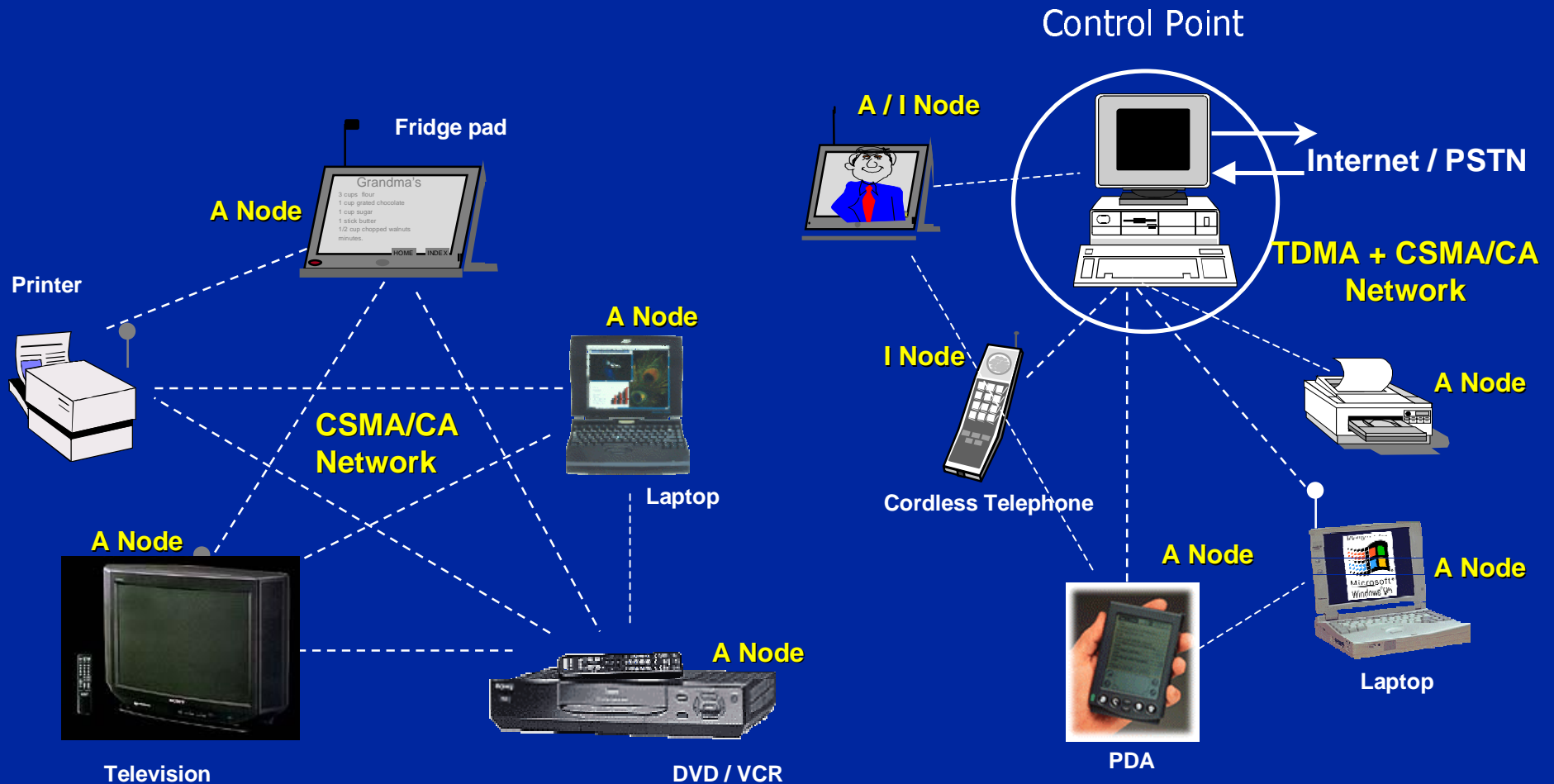
Power management +
Channel management

CSMA node
(power management) only

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HomeRF™ - Operational Modes



Peer-to-Peer Networking
Ad-Hoc Networking
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Managed Networking
(with or without PC)
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HomeRF™ - MAC Origins

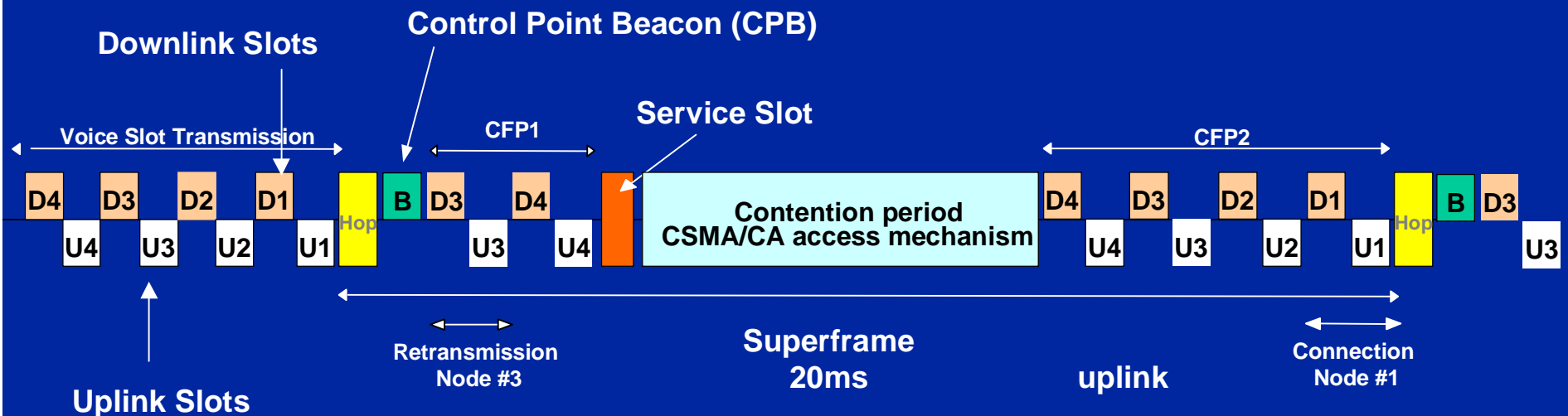
CSMA/CA
Good for Data

TDMA
Good for Voice



SWAP - CA
TDMA + CSMA/CA
Good for Voice & Data
Optimized for small networks

HomeRF™ - MAC (SWAP-CA)



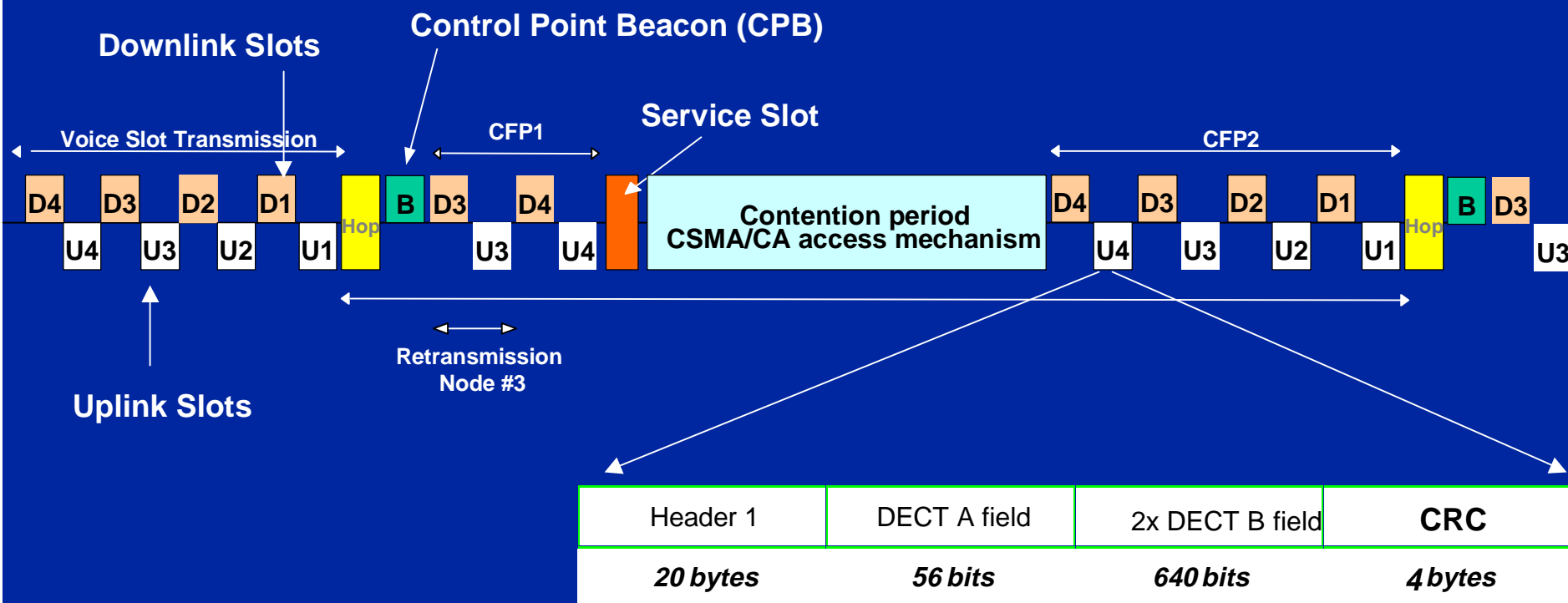
- **Beacon**

- Enables nodes to synchronize to hopping pattern of the network
- CPB - controls structure of the Superframe
- CPB - manages I-node connections through slot assignments
- enables power management in A-nodes

- With no voice connections the contention period occupies the entire Superframe

HomeRF™ - MAC (SWAP-CA)

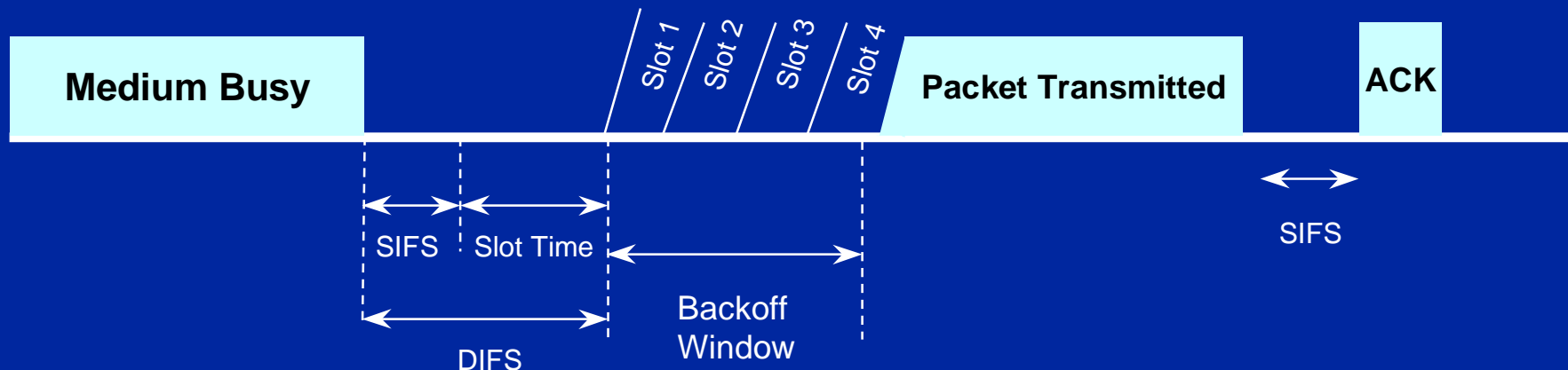
TDMA Access



HomeRF™ - MAC (SWAP-CA)

CSMA/CA Access

Listen Before Talk

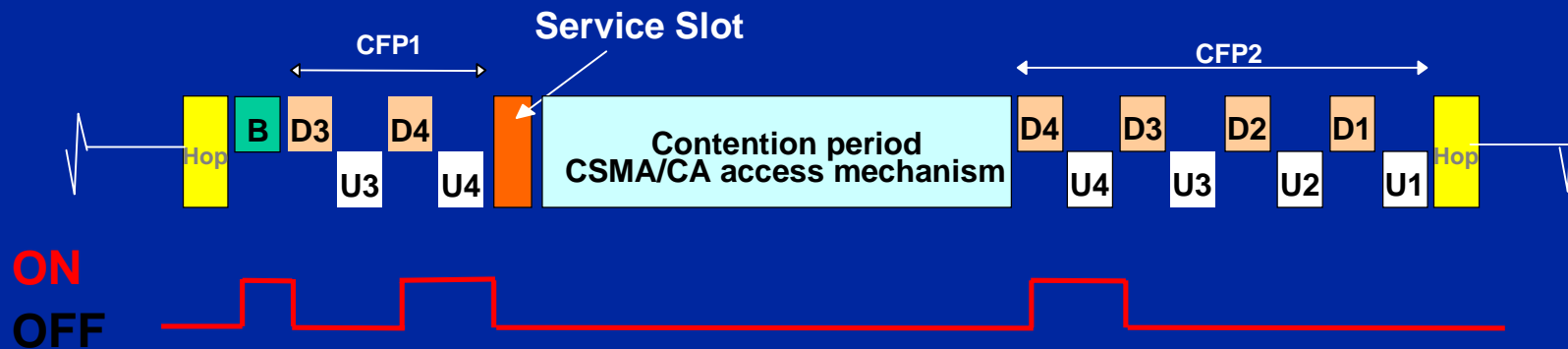


Collision Avoidance:

- Set **Backoff** counter to a random value
- If the medium is free for DIFS period, decrement the counter
- If medium is active suspend the countdown
- Wait a DIFS before resuming the countdown
- When backoff counter expires - transmit

HomeRF™ - Power Management

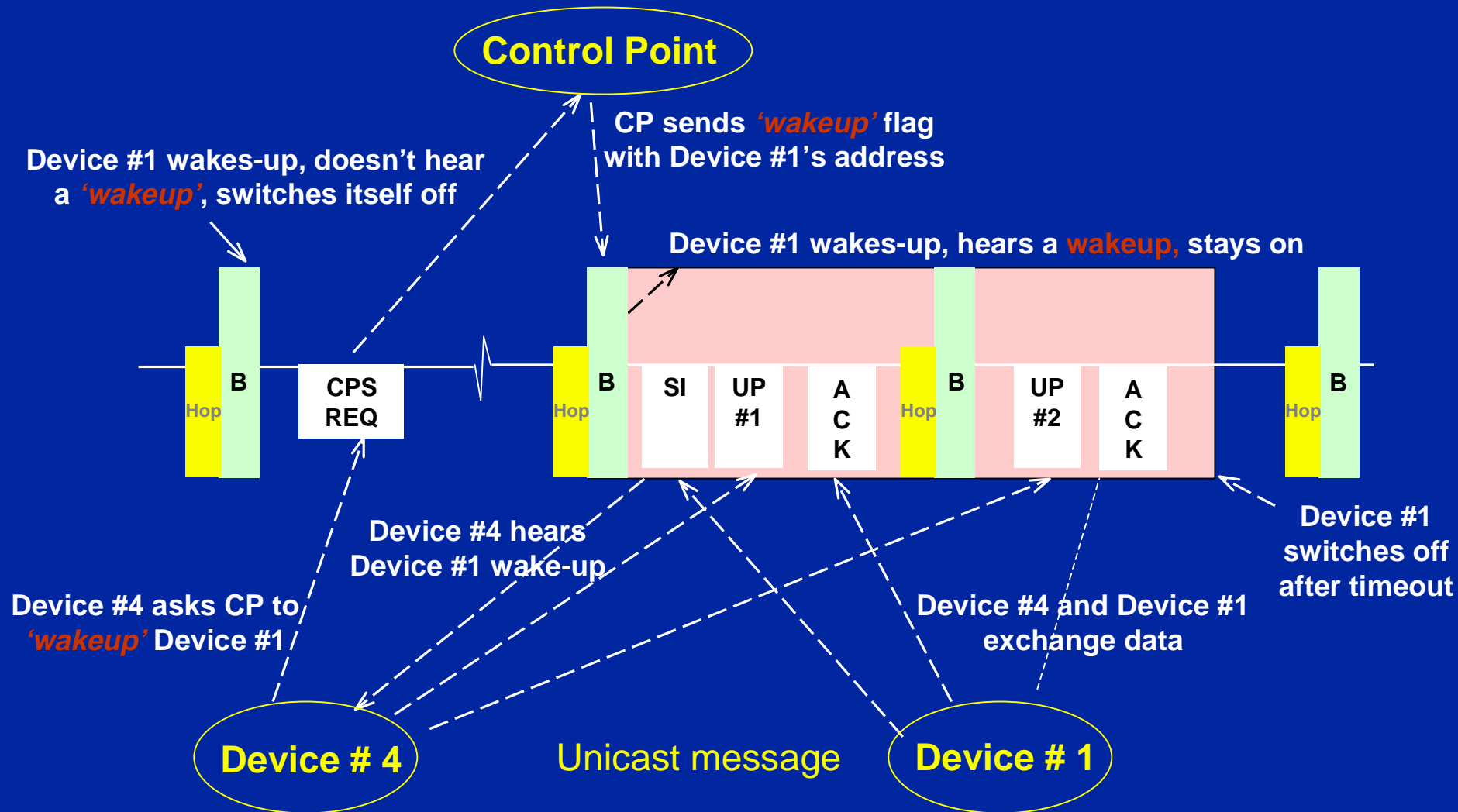
For TDMA Nodes



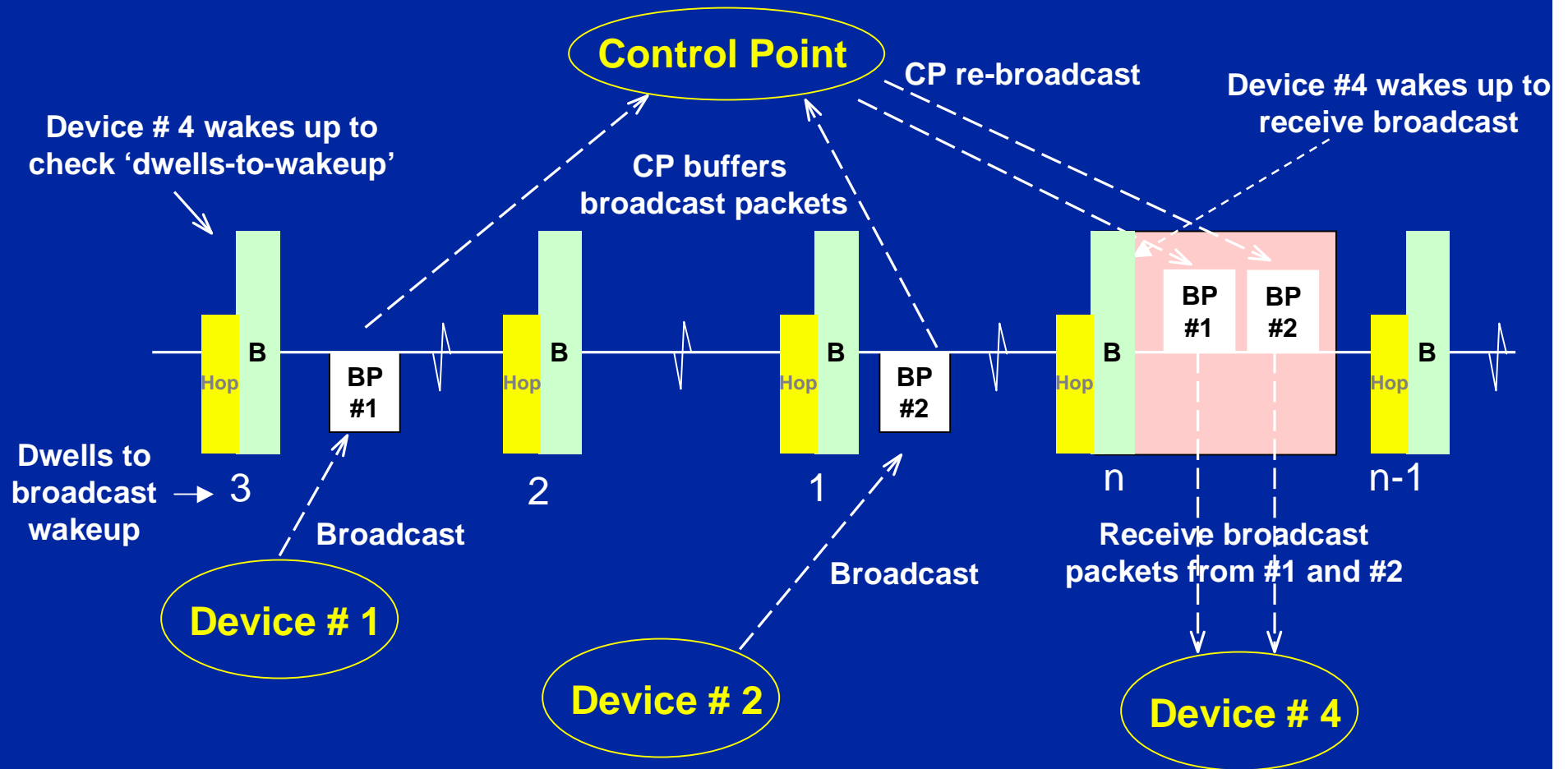
- Devices switch-on periodically to receive a Beacon if they do not have an active connection
- If they have an active connection they switch on:
 - to receive the Beacon
 - switch on for transmissions in CFP2
 - switch on for any re-transmissions in CFP1
- At all other times they can be switched off

HomeRF™ - Power Management

For CSMA Nodes

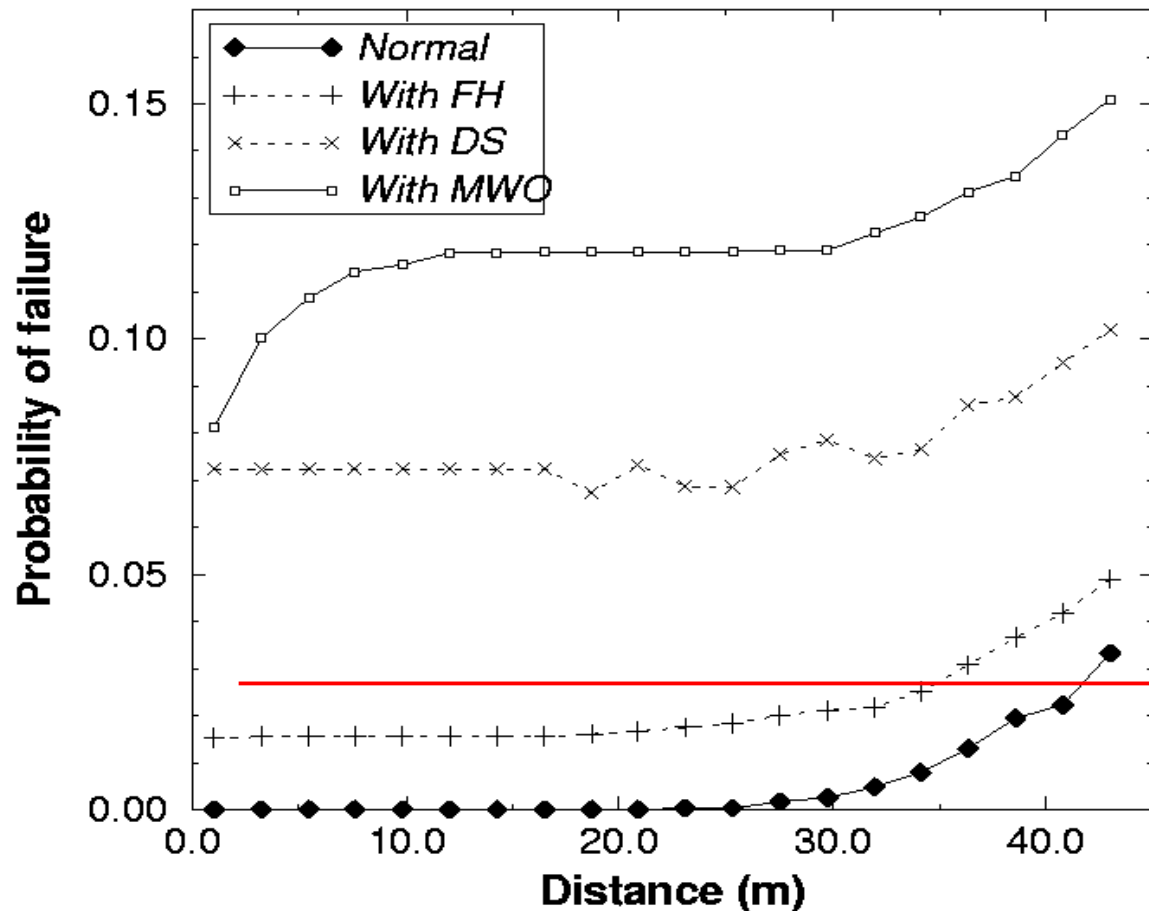


For CSMA Nodes



Broadcast messaging

Voice Traffic: Raw Packet Failure Rate .vs. Distance

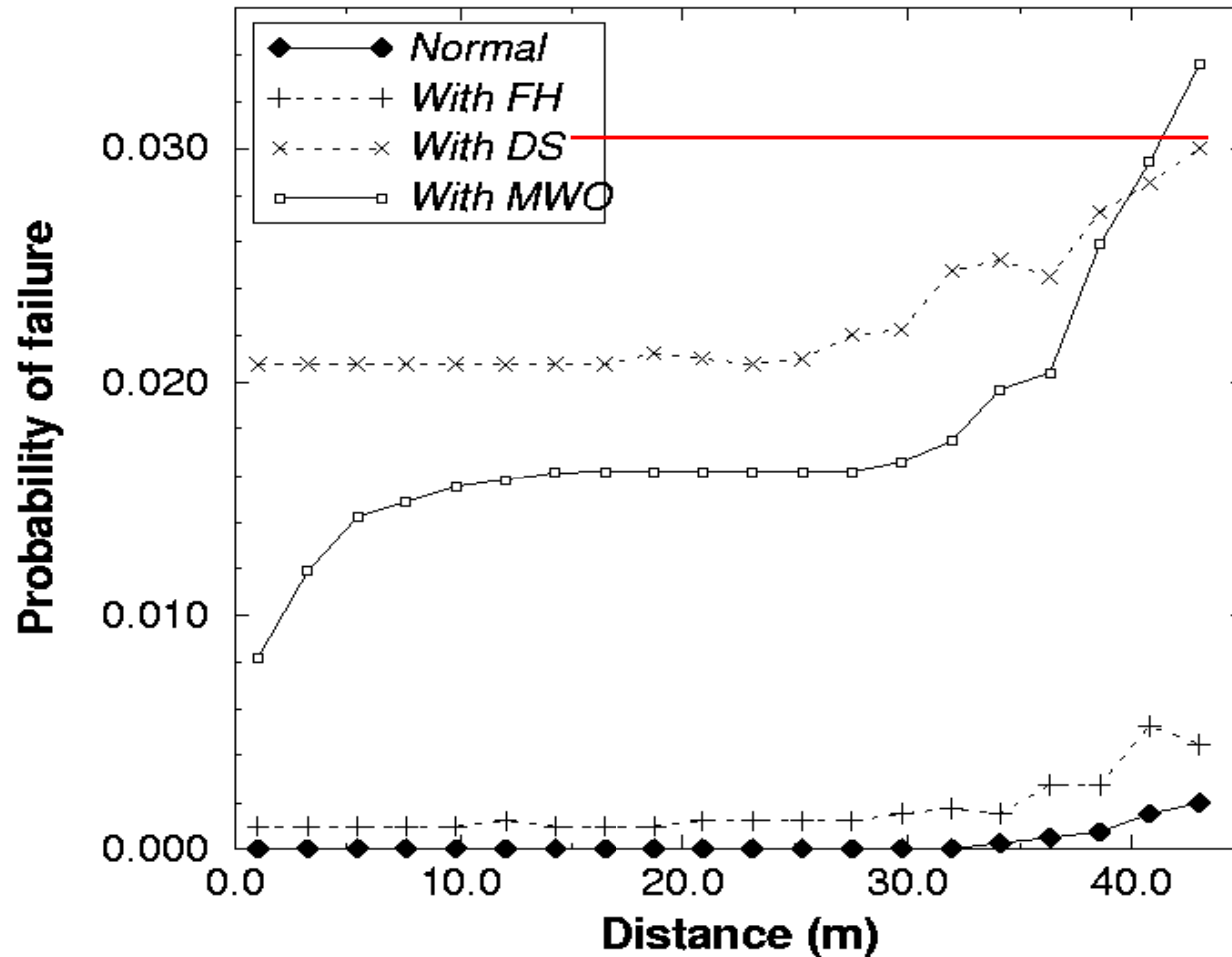


4 voice connections,
ADPCM codec generating
a 640 bit packet every
20ms

Acceptable packet failure
rate = 3%

Source:
Romans & Tourrilhes,
PIMRC'98

Voice Traffic Packet Failure .vs. Distance - with SWAP

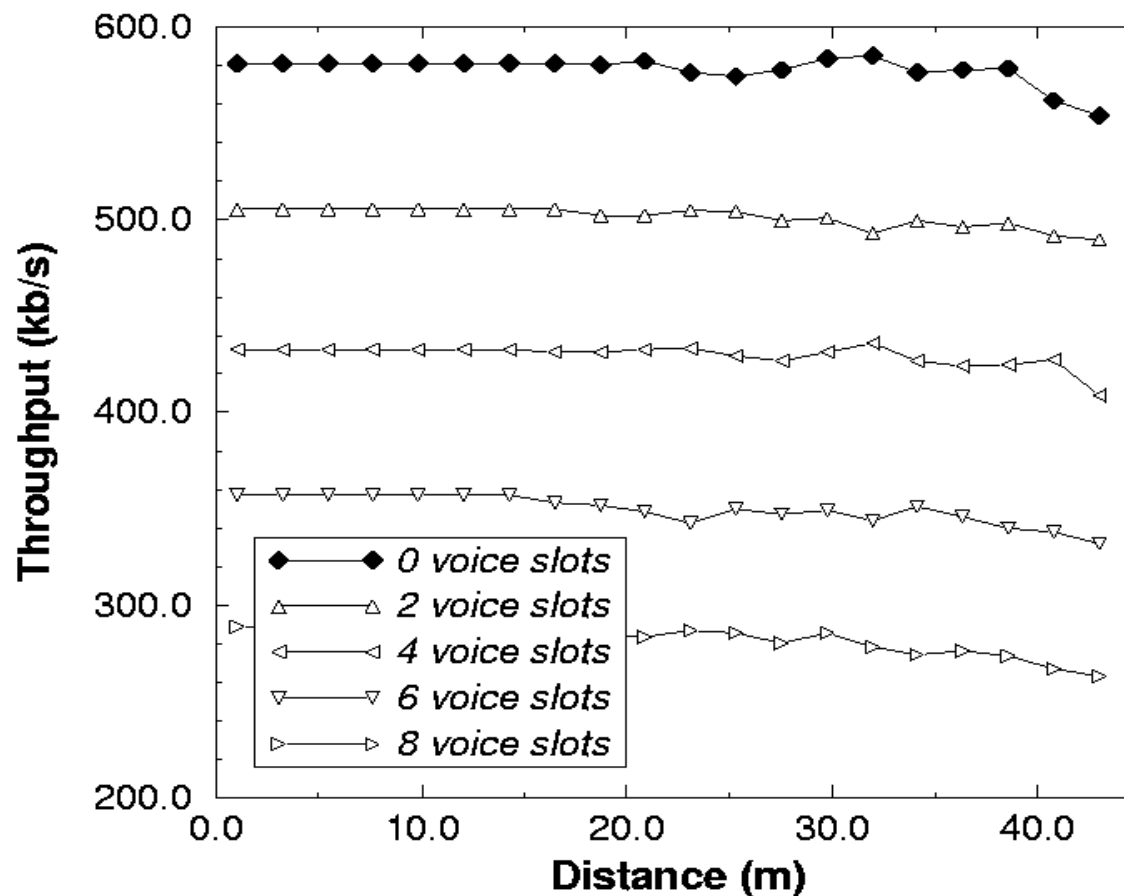


Acceptable packet failure
rate = 3%

Source:
Romans & Tourrilhes,
PIMRC'98

Data Traffic

Maximum Throughput .vs. Distance

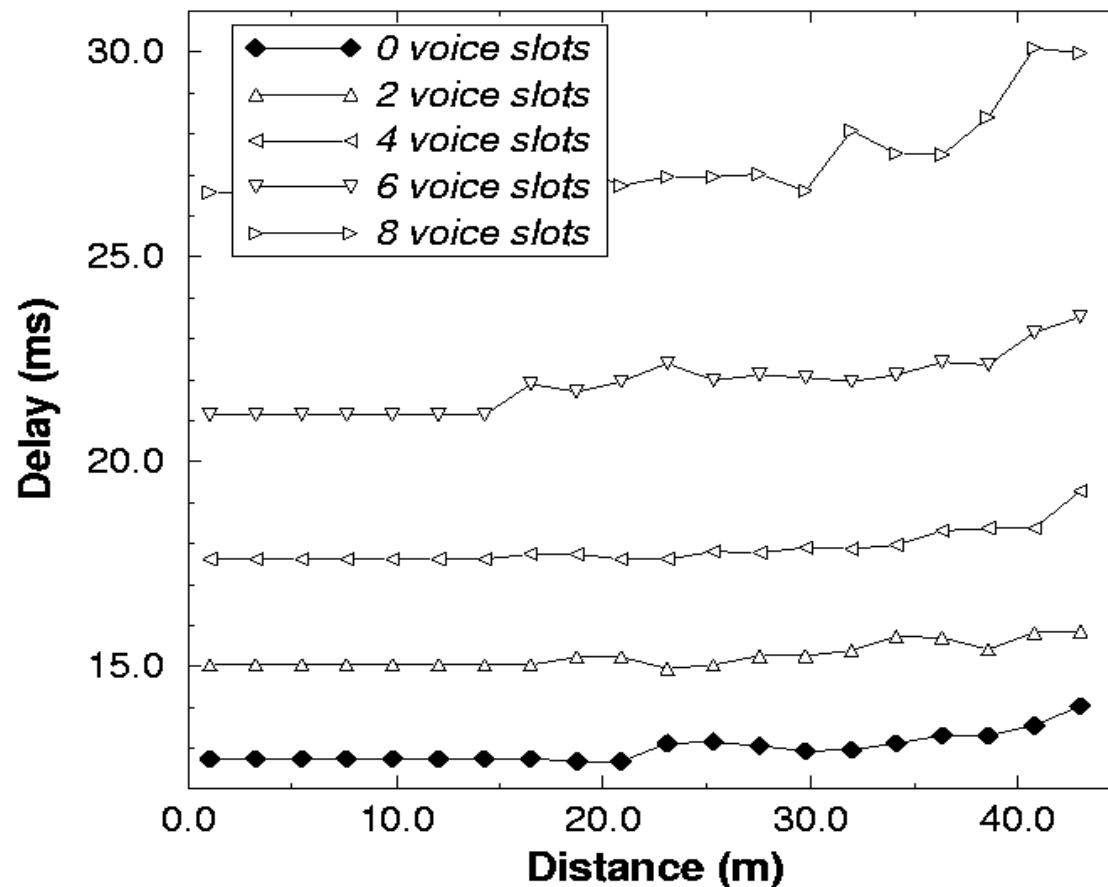


As more voice connections are added the data throughput drops - but with 8 voice slots still delivers 250 kbit/s

Source:
Romans & Tourrilhes,
PIMRC'98

Data Traffic

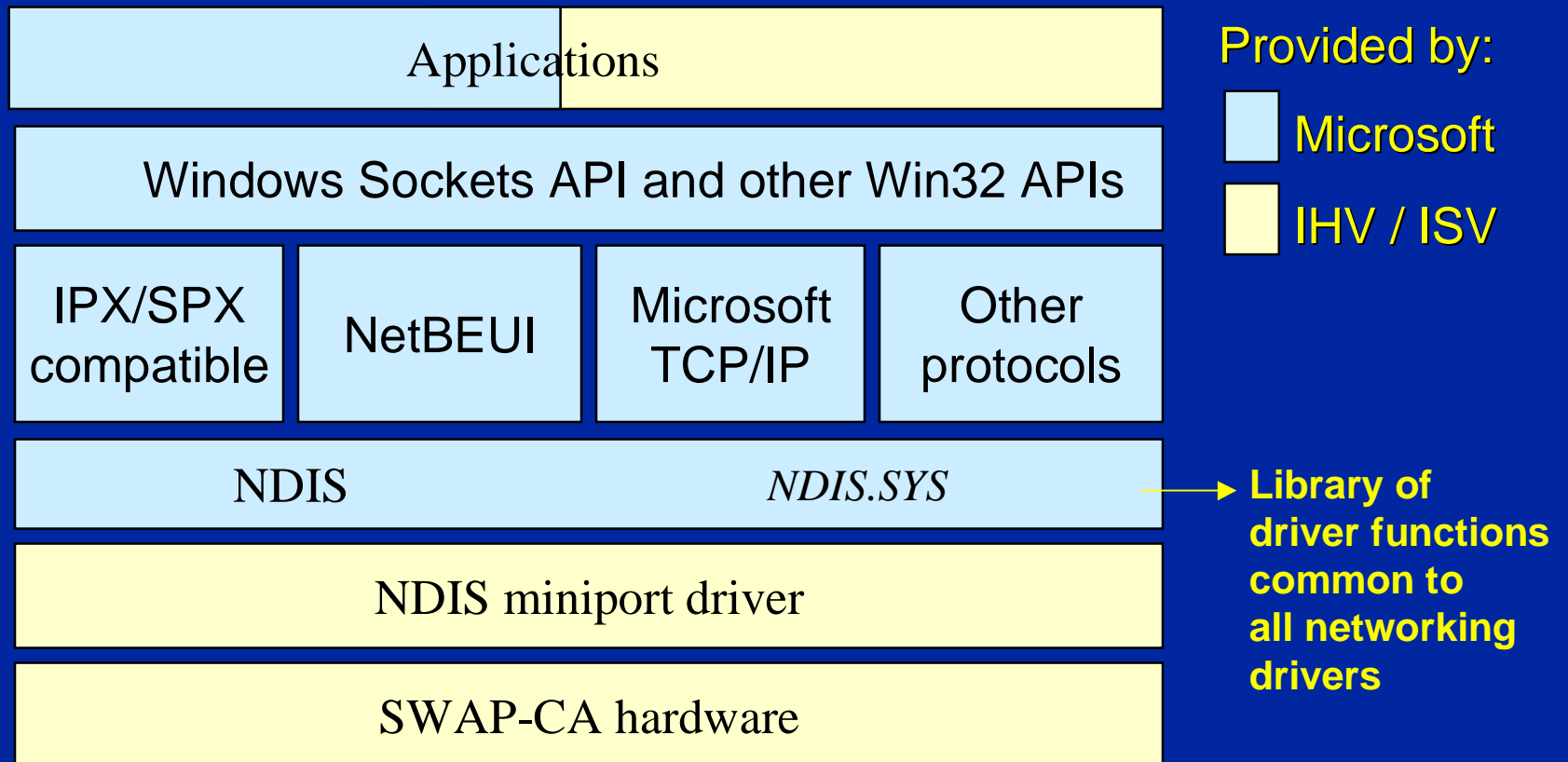
Average Network Delay vs Distance



Source:
Romans & Tourrilhes,
PIMRC'98

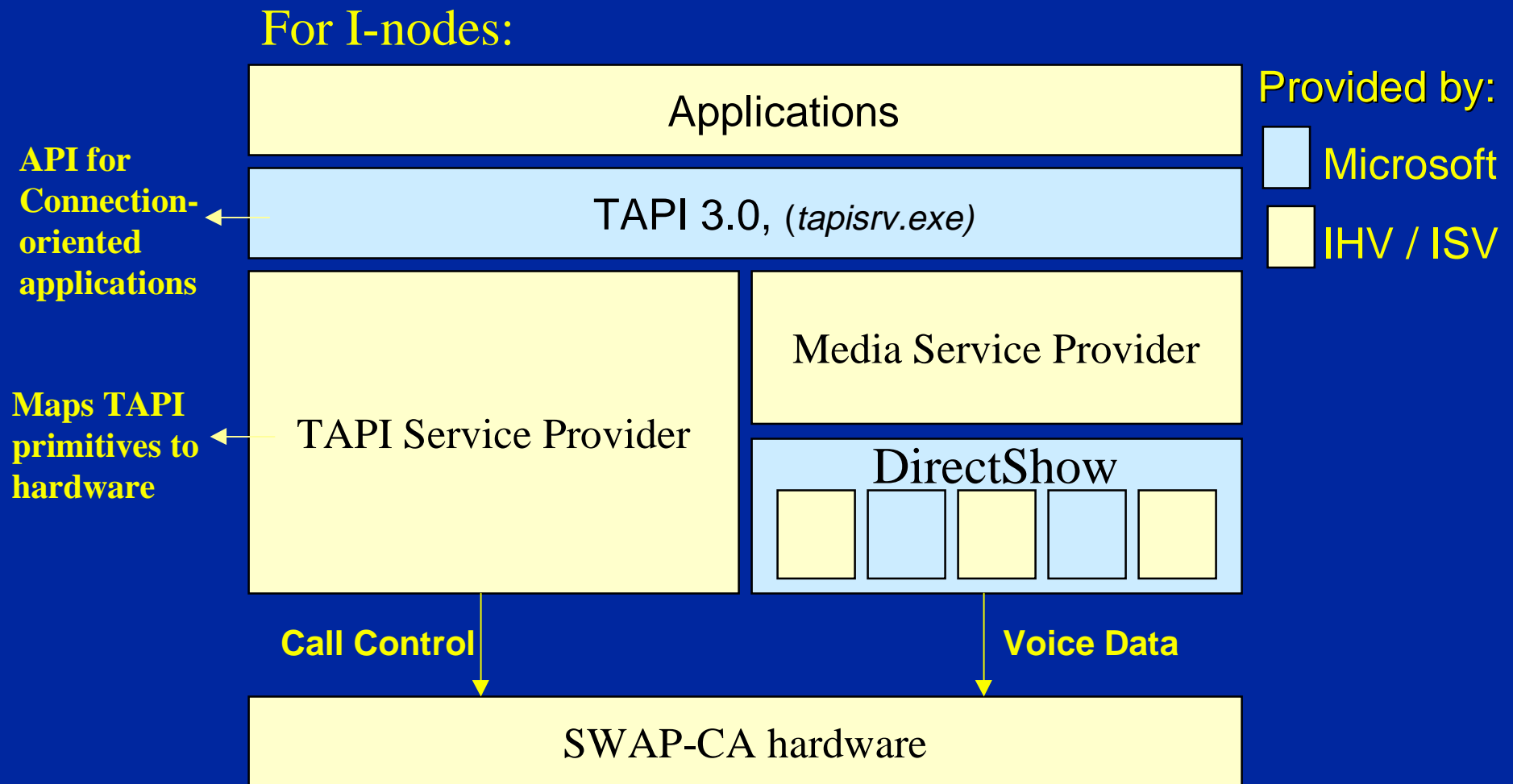
HomeRF™ - Software (MS Windows)

For A-nodes:



Looks like, behaves live Ethernet !

HomeRF™ - Software (MS Windows)



HomeRF™ - Synopsis

- Supports both circuit-switched and packet-switched communications - designed for both PSTN-type and TCP/IP-type communications
 - Supports up to 127 device / network
 - Different levels of security built in
-
- Hybrid TDMA / CSMA frame
 - Supports up to 6, low-latency 32 Kbps ADPCM I-nodes
 - many A-nodes
 - Slow frequency hopping system -- 50 hops/sec
 - hop sequence is localized based on country
 - 2 FSK yields 1 Mbps (standard), 4 FSK yields 2 Mbps (Optional)
 - Range up to 50 meters (0 / +20 dBm)
-
- Frequency and time diversity to combat interference from co-located DS and FH systems

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Bluetooth - Mission Statement

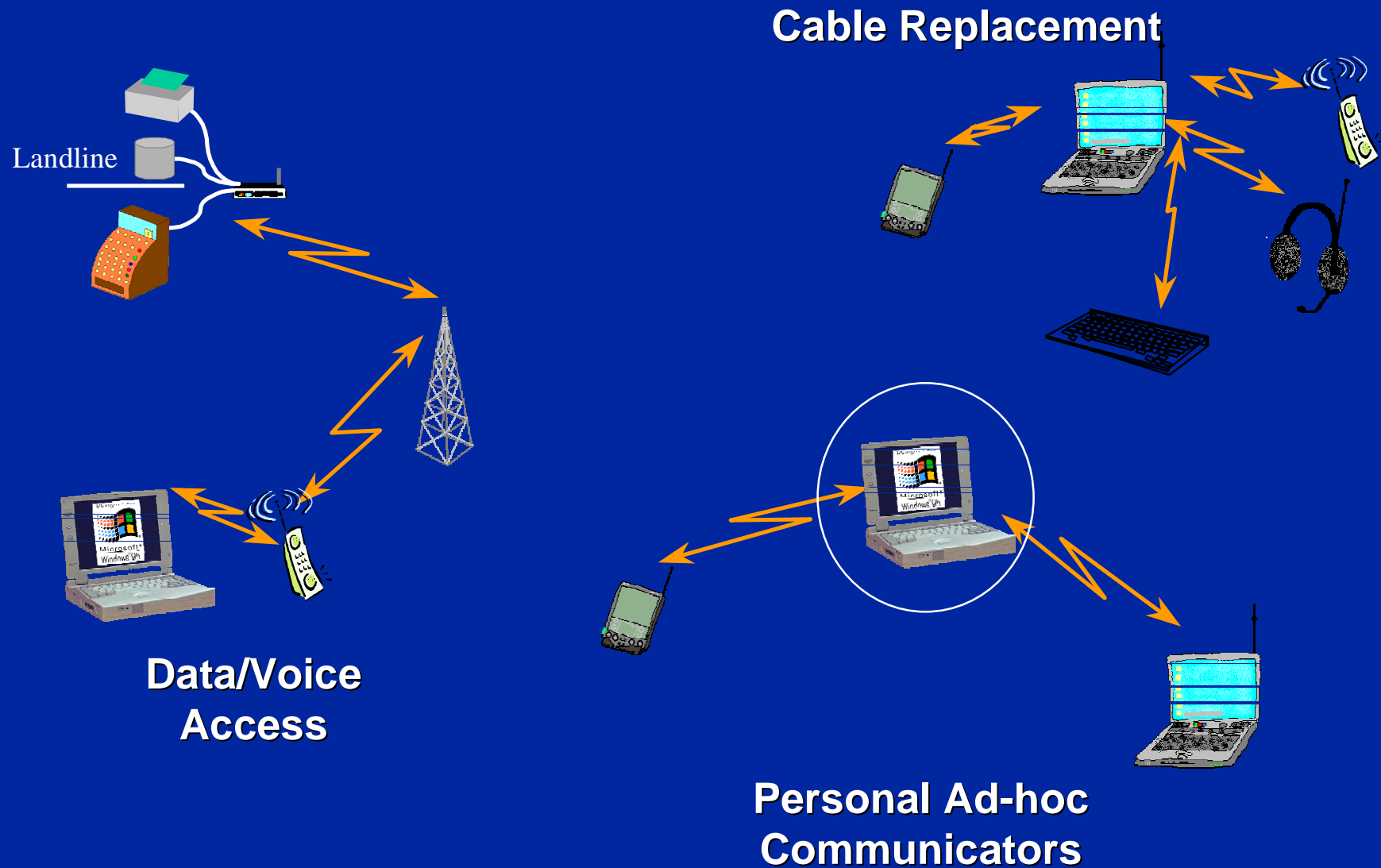
“Bluetooth technology allows of the replacement of many propriety cables that connect one device to another with one universal short-range radio-link”

- <http://www.bluetooth.com/technology/default.asp>



Harald Blaatand "Bluetooth" II
King of Denmark 940-981

Bluetooth - Vision



Bluetooth - Usage Models

Bluetooth (www.bluetooth.com)

- Applications Galore
 - The three-in-one phone
 - The interactive conference
 - The Brief-case trick (hidden computing)
 - The Automatic Synchronizer
 - The Forbidden Message
 - The instant postcard
 - The Portable Speaker Phone
 - The Cordless Desktop
 - The Ultimate Headset
 - The Internet Bridge

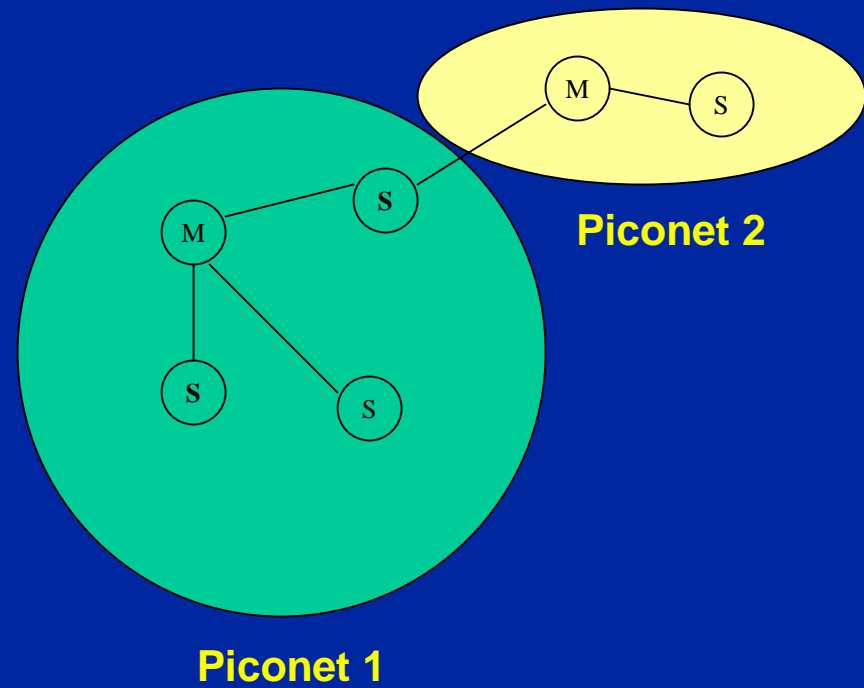
Bluetooth - Design Goals

- + Operational Spectrum -- 2.4 GHz (world wide availability)
- + Data rate
 - 700 Kbps asynchronous (data) traffic OR
 - up to 3, 64 Kbit/sec isochronous (Voice) connections
- + Range -- 10 m (devices have to be in close proximity to each other)
- + Mobility -- no support
- + Communications -- Packet oriented, master-slave
 - no infra-structure required -- ad hoc, point-to-point, point-to-multipoint
- + Simultaneous support for isochronous and asynchronous traffic
 - Continuous Variable Delta Modulation (CVSD) @ 64 Kbps
- + Ultra Low power standby mode
 - + Standby mode, units wakeup every 1.28 seconds, or 2.56 seconds

Bluetooth - Network Architecture

Hierarchical

- **Peer-to-peer communications**
 - Device can be a master or a slave
 - All devices can become masters
- **Piconet**
 - All devices hop in sync. with the master
 - Master can connect up to 7 slaves simultaneously
 - Each piconet has a unique 48 bit network ID
- **Scatternet**
 - Radios can share piconets
 - Up to 10 piconets within range



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Comparison

<i>Properties</i>	<i>HomeRF™</i>	<i>Bluetooth</i>	<i>IEEE 802.11</i>
Operational Spectrum	2.404 - 2.478 GHz	2.402 - 2.480 GHz	2.400 - 2.4835 GHz / Optical
Physical Layer	FHSS. 50 hops/sec	FHSS, 1600 hops/sec	DSSS / FHSS / IR
Channel Access	Hybrid of TDMA & CSMA/CA	Master-Slave, TDMA	CSMA/CA
Raw Data Rate	1 and 2 Mbps	1 Mbps	1 and 2 Mbps
Range	< 150 feet	< 30 feet	150 feet
Power Consumption	100 mWatt	?	- <i>Not specified</i> -
Traffic	voice + data	voice, data	Data (DCF)
Error Robustness	CRC / ARQ Type I	1/3 rate FEC, 2/3 rate FEC and ARQ Type 1	CRC / ARQ Type II
Mobility Support	- <i>Not applicable</i> -	- <i>Not applicable</i> -	- <i>Not specified</i> -
Energy Conservation	Yes	Yes	Directory based
Guaranteed Latency	< 20 msec for voice	?	None
Speech Coding	32 Kbps with ADPCM	64 kbps with CVSD / logPCM	- <i>Not specified</i> -
Security	Blowfish encryption	Minimal built-in PHY	64-bit Key & RC4
Communication Topology	Peer-to-Peer, MS-to-BS	Master-slave, master to multi-slave	Peer-to-Peer, MS-to-BS
Price Point (estimate)	\$30 /1999; \$18 /2000	\$20 /1999; \$10 /2000	\$100/'99 - \$25/2000

Possible Technology Positioning

	Cable Replacement	Peer-to-peer Networking	Voice-centric Telephony	Voice & Data Networking
Enterprise	Bluetooth/IrDA	802.11	?	?
Home	Bluetooth/IrDA	HomeRF-data	?	HomeRF-full
Mobile	Bluetooth/IrDA	?	Cellular	3G

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Conclusions

The elements for a revolution are coming together

- **Bluetooth** - is a cable replacement technology optimized for the mobile warrior. It makes sense for point to point communication, low data rates connections.
- **HomeRF™** - is a networking technology optimized for tetherless home networking and telephony. Work on developing a higher data rate multimedia standard is underway.
- **IEEE 802.11** - is a networking technology for the enterprise. Supports roaming. Work on a higher data rate standard is in full swing.

References

- 1 HomeRF URL: <http://www.homerf.org>
- 2 Bluetooth URL: <http://www.bluetooth.com>
- 3 K. J. Negus, J. Waters, et. al, "HomeRF and SWAP: Wireless Networking for the Connected Home," *ACM Mobile Computing and Communications Review (MC²R)* , Vol. 2, No. 4 (October 1998): 28-37
- 4 J. Haarsten, et. al., "Bluetooth, Vision, Goals, and Architecture," *ACM Mobile Computing and Communications Review (MC²R)* , Vol. 2, No. 4 (October 1998): 38-45
- 5 Mahmoud Naghshineh (IBM), Bluetooth presentations at MobiCom '98 (Dallas) and PIMRC '98 (Boston)
- 6 Chris Romans and Jean Tourrilhes, "A Medium Access Protocol for Wireless LANs which supports Isochronous and Asynchronous Traffic," *IEEE PIMRC '98*, Boston, Massachusetts, USA, Sept. 8-11, 1998