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

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This presentation has been prepared using materials that are publicly available. The accuracy of the information is therefore limited to what is in these available documents and presentations. References from which this presentation was developed are provided at the end of the talk.

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

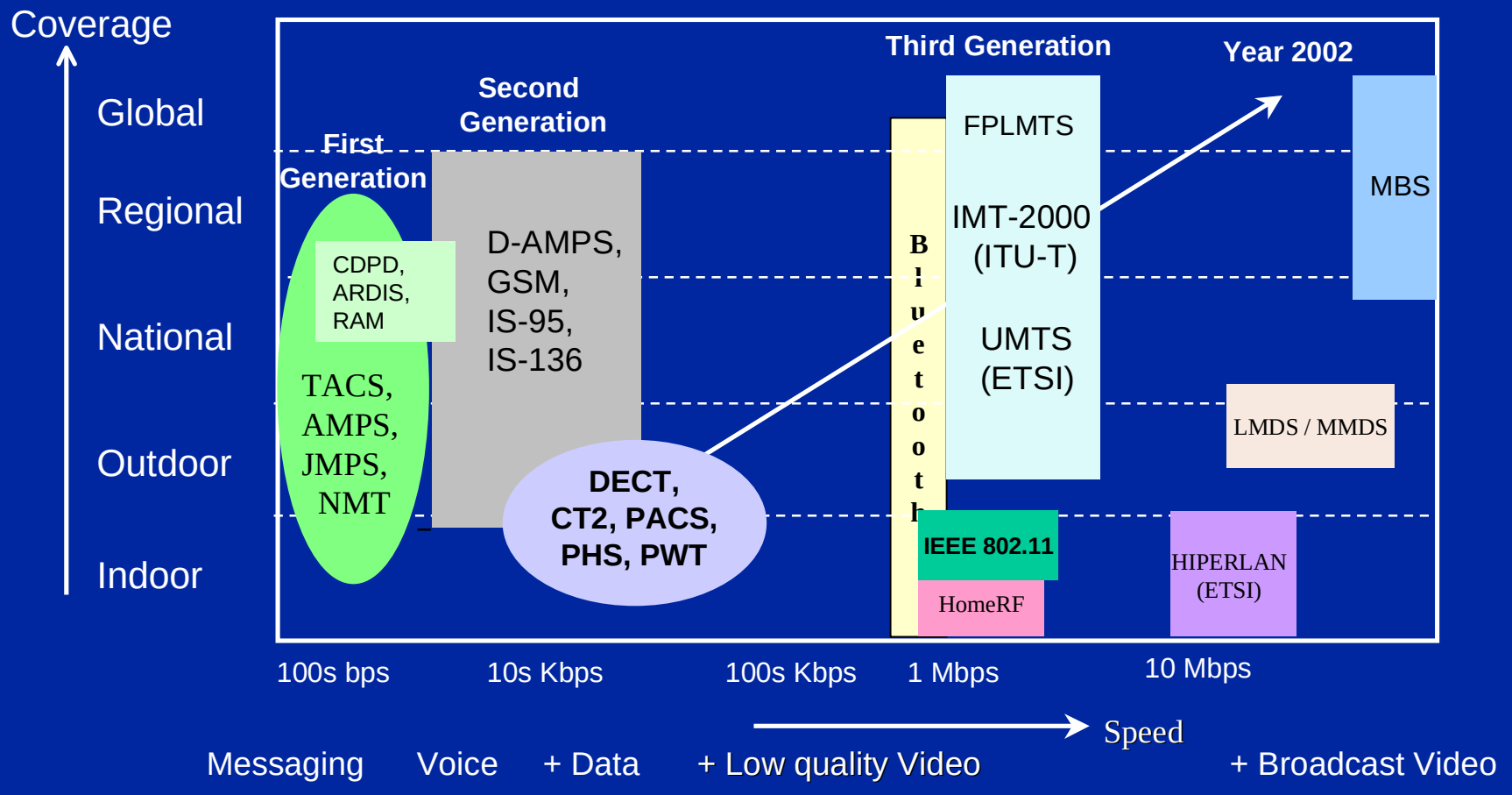
- Mostly heterogeneous traffic -- voice + data + video, (packet switched)
- Ubiquitous
- Generic network API
- Fixed network protocols with radio and mobile plug-ins
- High usage
- High bit-rates
- Mass market cost/performance
- Secure
- Multi-hop self configuring networks

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

In the Grand Scheme of Things

Past, Current, and Future



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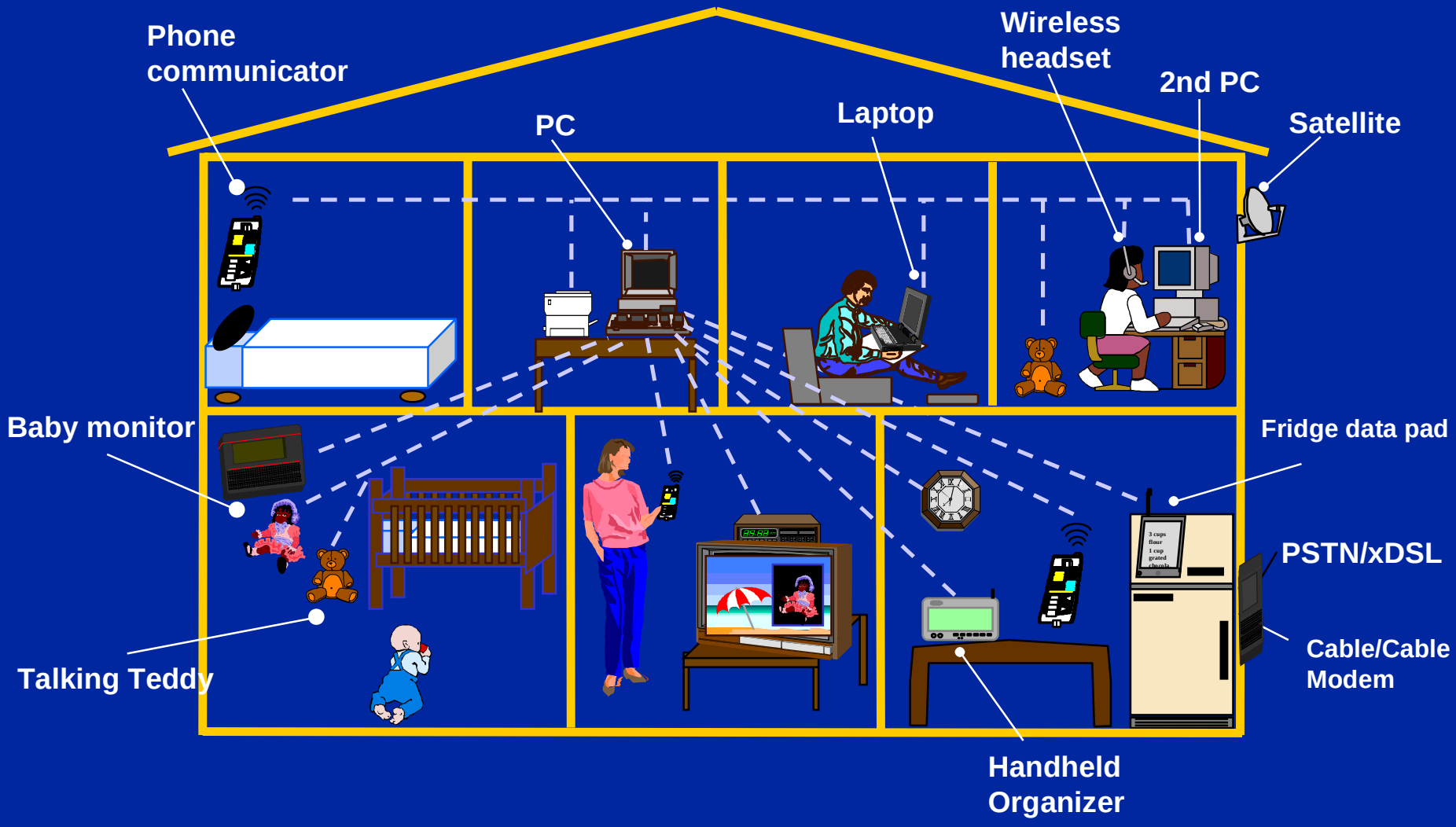
HomeRF™ - Mission Statement

"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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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.

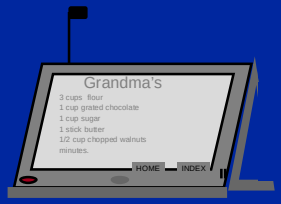
HomeRF™ - Design Goals

- 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 sensivity -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

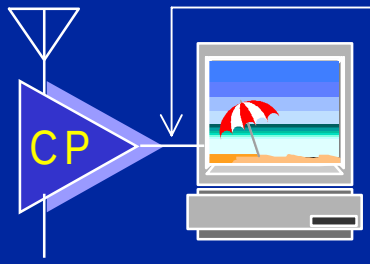
Cordless Telephone

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



Pad

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



PSTN

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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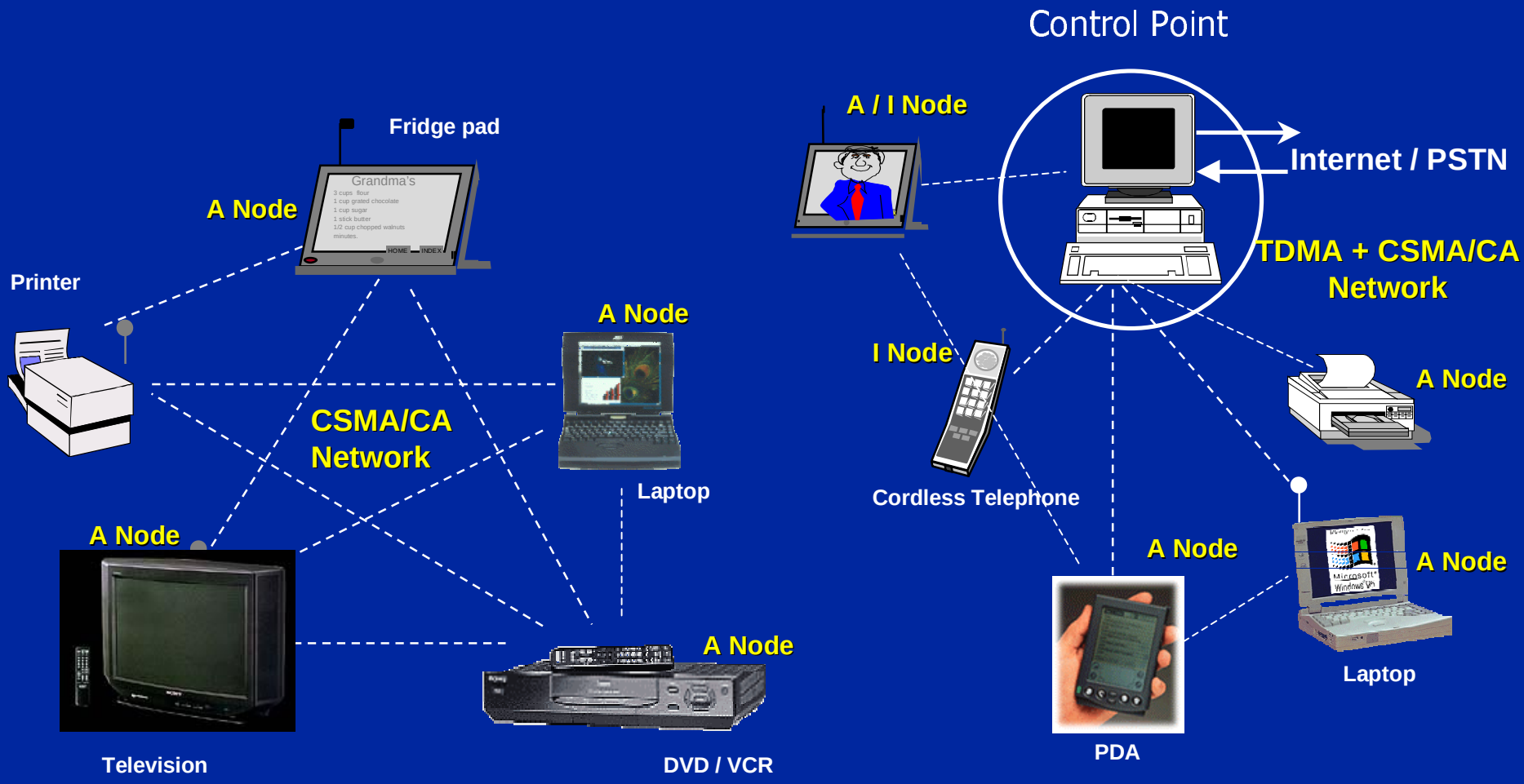
HomeRF™ - Operational Modes



Peer-to-Peer Networking
Ad-Hoc Networking

Managed Networking
(with or without PC)

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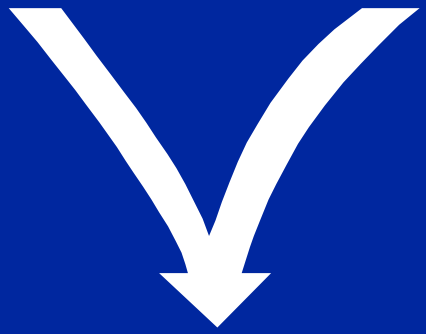
HomeRF™ - MAC Origins

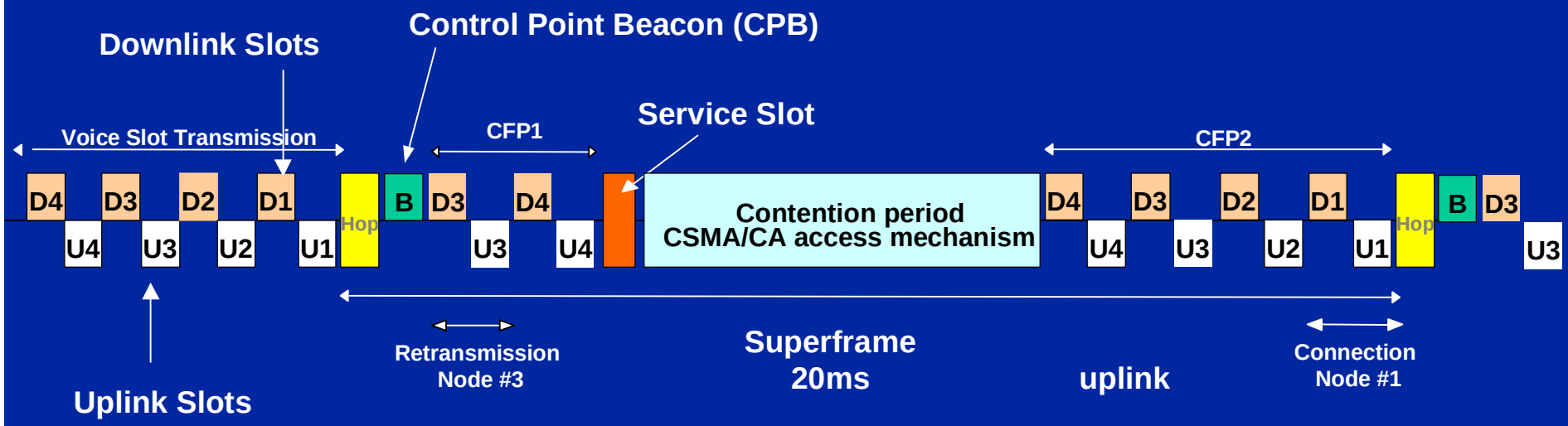
CSMA/CA
Good for Data

TDMA
Good for Voice



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

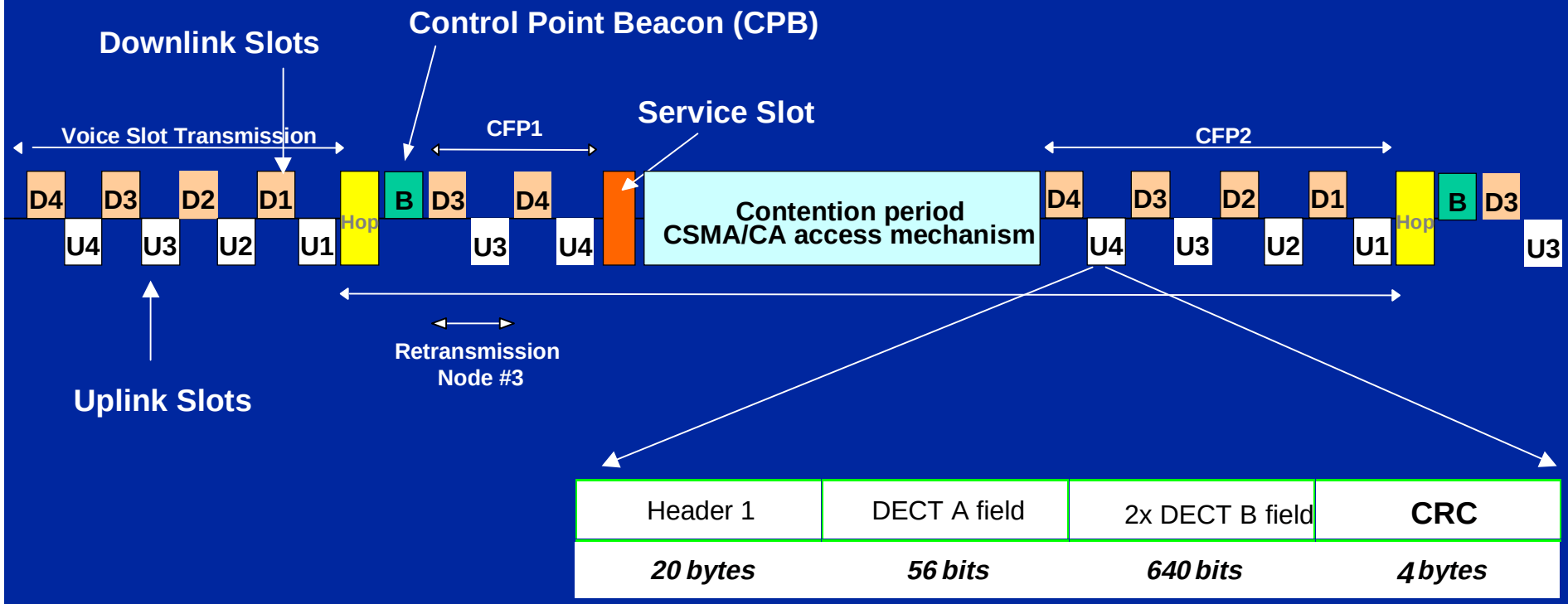
HomeRF™ - MAC (SWAP-CA)



- 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



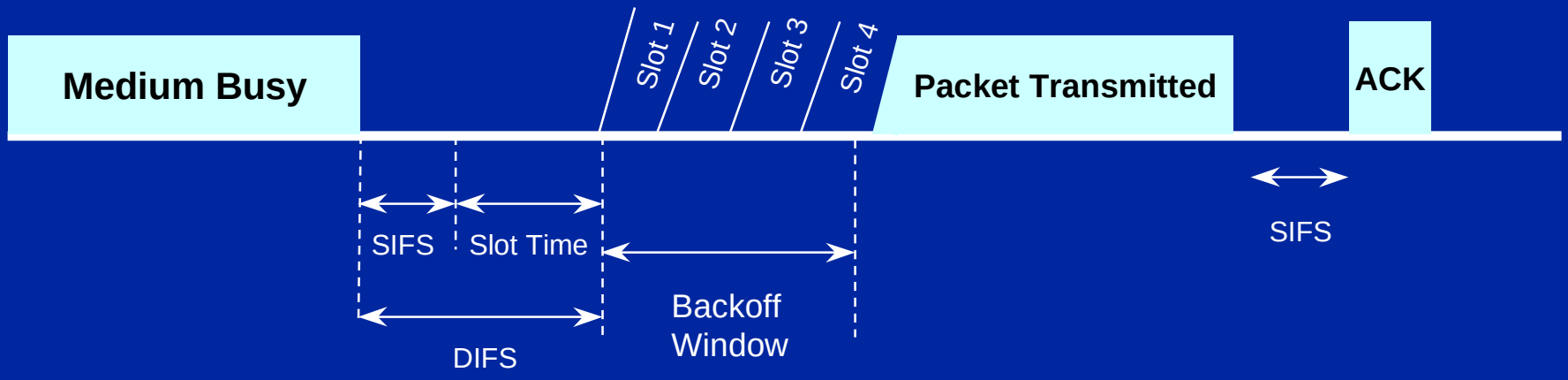
Header 1	DECT A field	2x DECT B field	**CRC**
20 bytes	***56 bits***	***640 bits***	***4 bytes***

DECT Stack mandated above the MAC

HomeRF™ - MAC (SWAP-CA)

CSMA/CA Access

Listen Before Talk

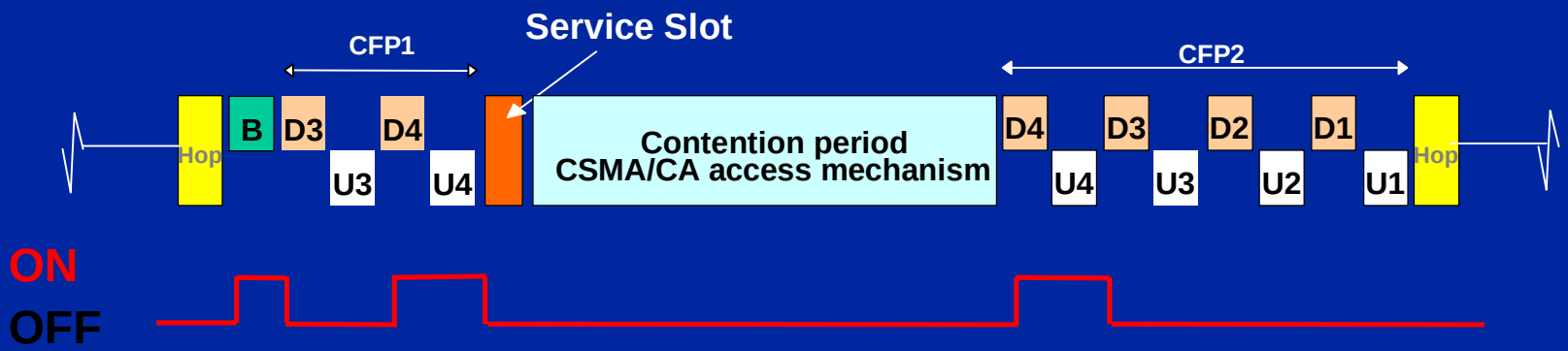


Collision Avoidance:

- **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

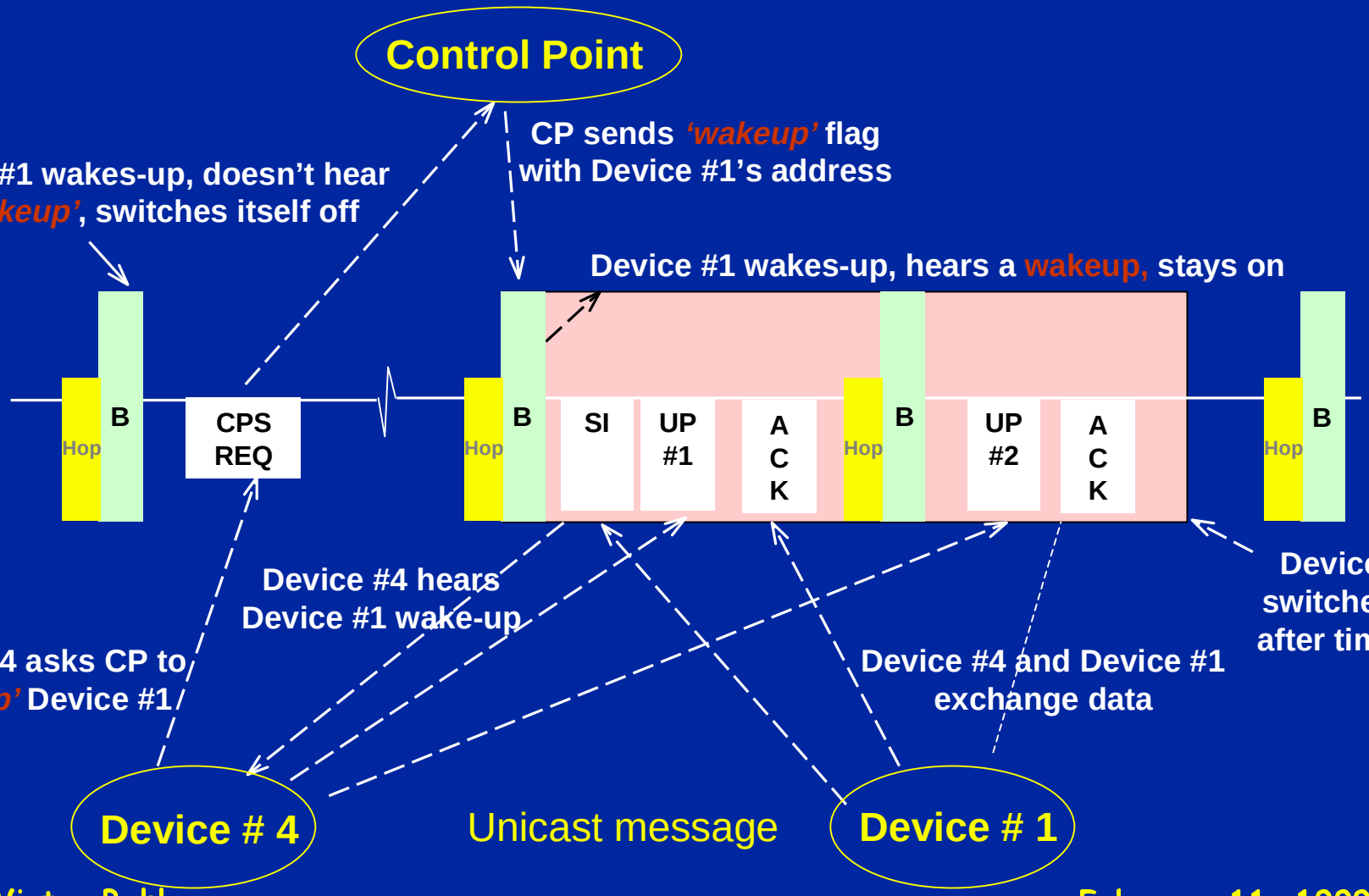
For TDMA Nodes



- 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-transmissons in CFP1
- At all other times they can be switched off

HomeRF™ - Power Management

For CSMA Nodes



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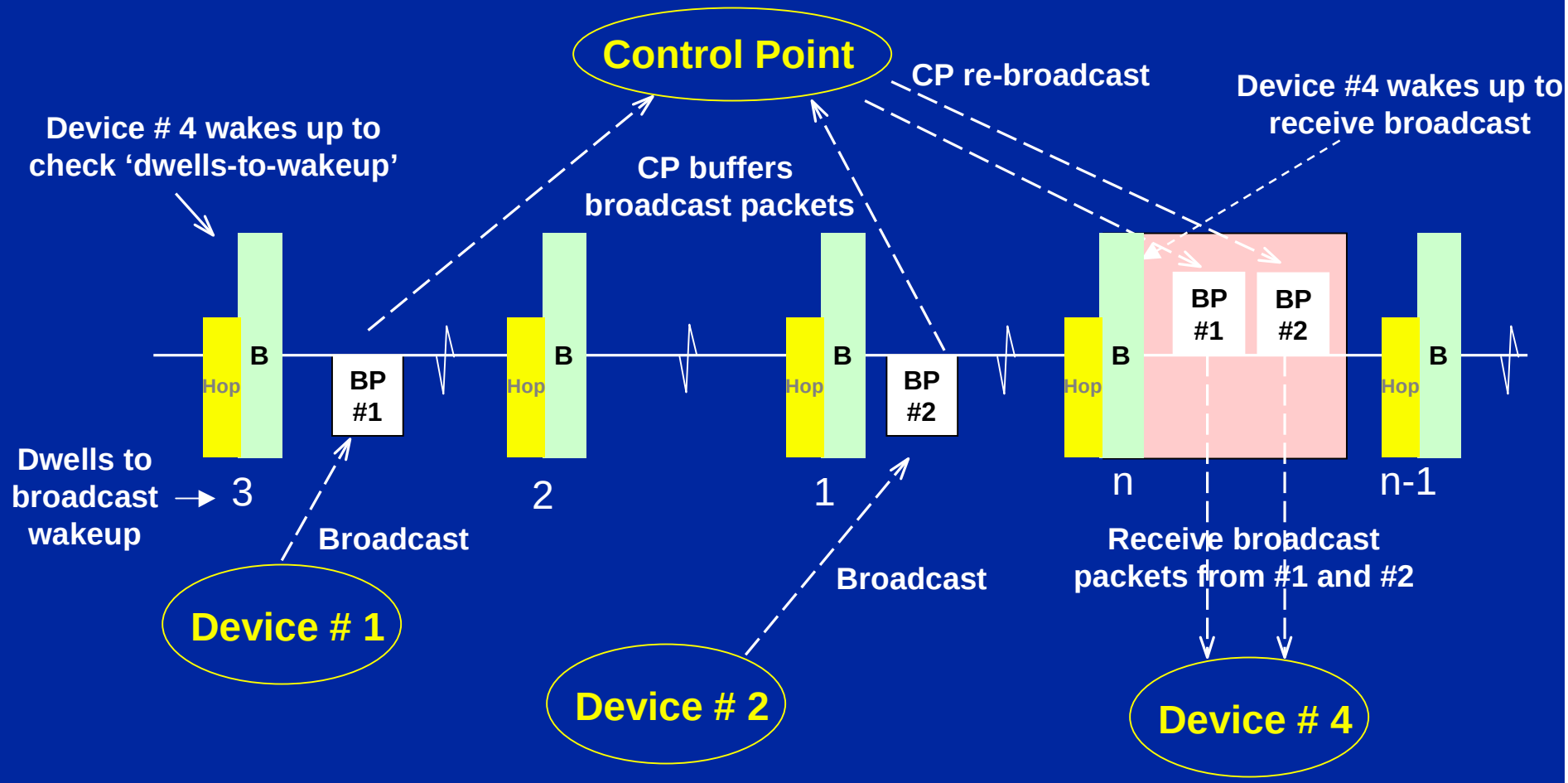
HomeRF™ - Power Management

For CSMA Nodes



Broadcast messaging

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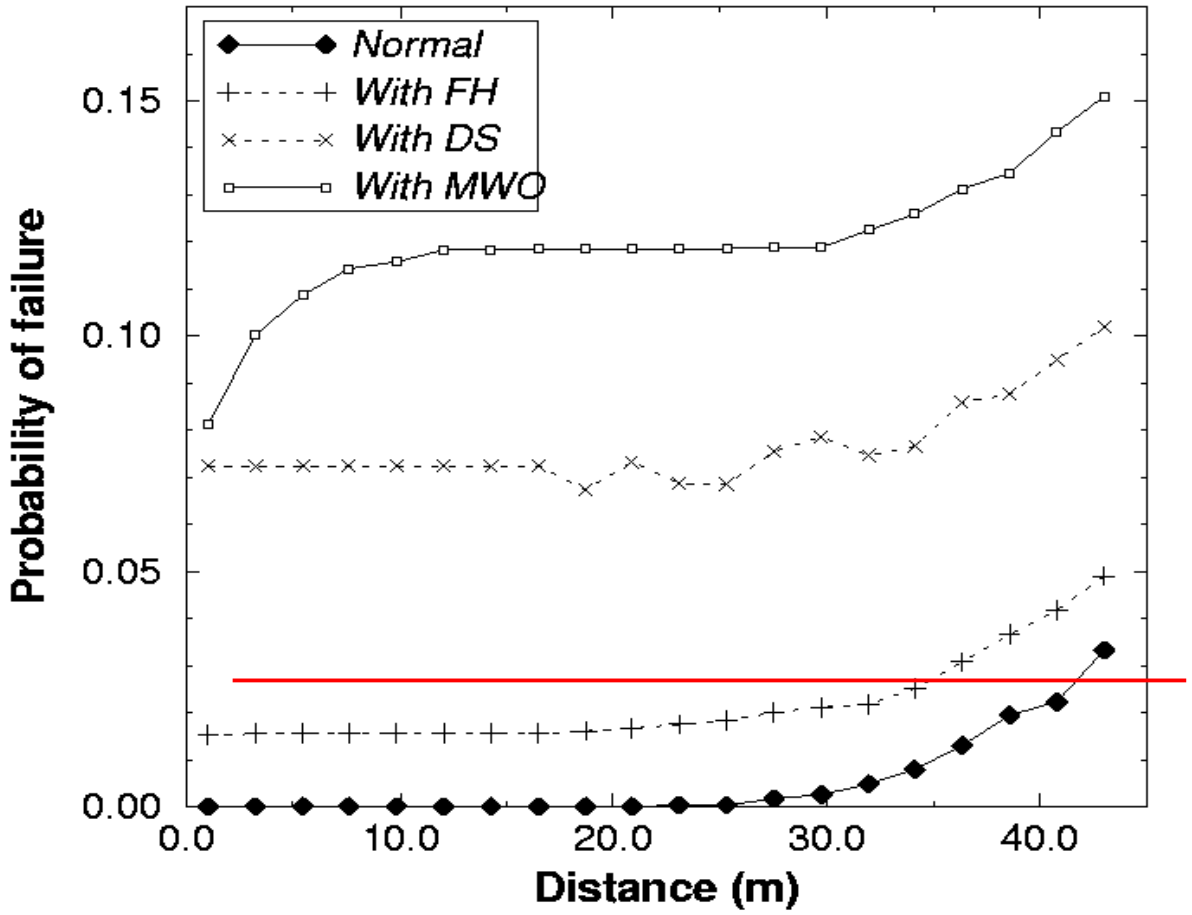
Voice Traffic:
Raw Packet Failure Rate .vs. Distance

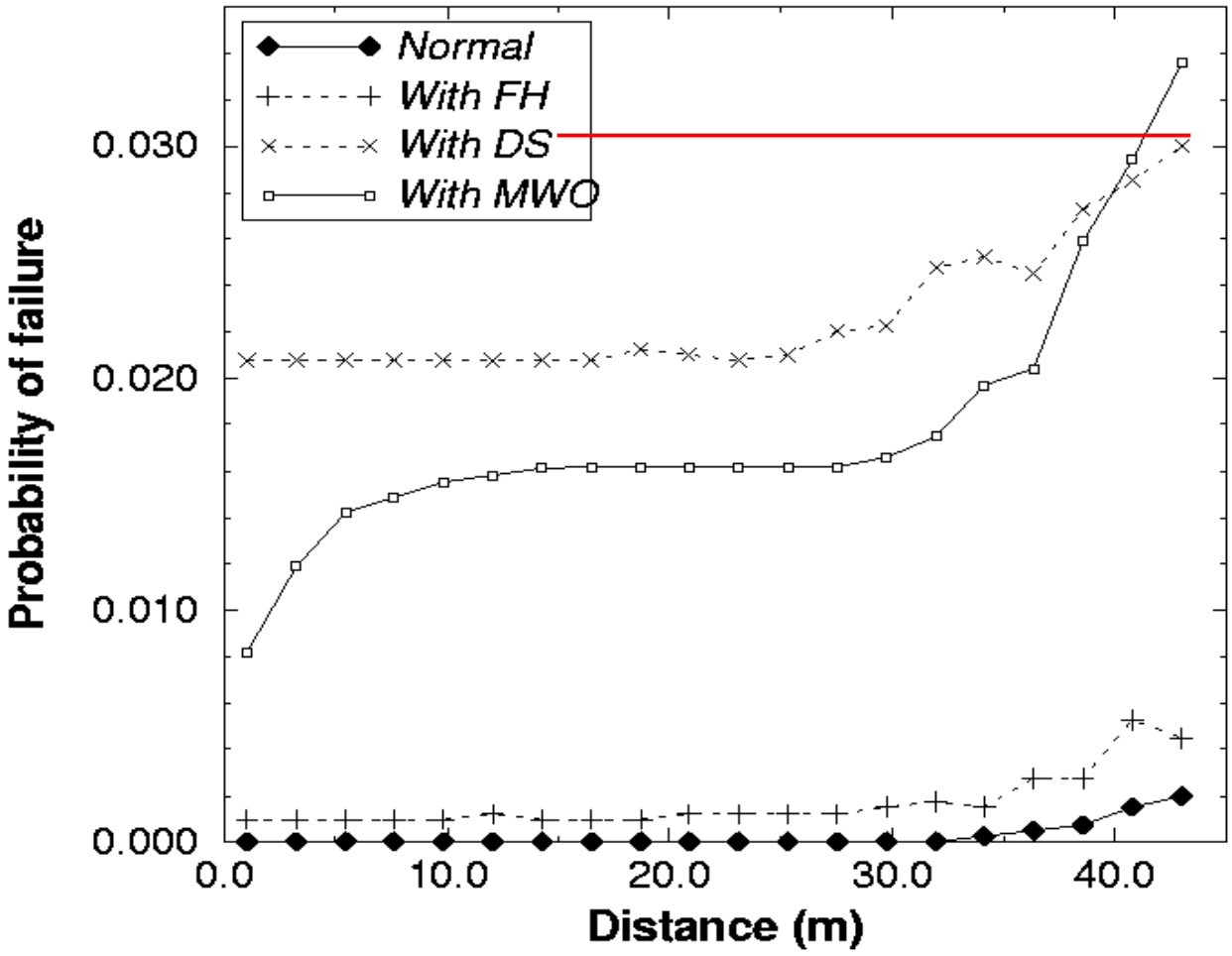


4 voice connections, ADPCM codec generating a 640 bit packet every 20ms

Acceptable packet failure rate = 3%

Source:
Romans &Tourrilhes, PIMRC'98

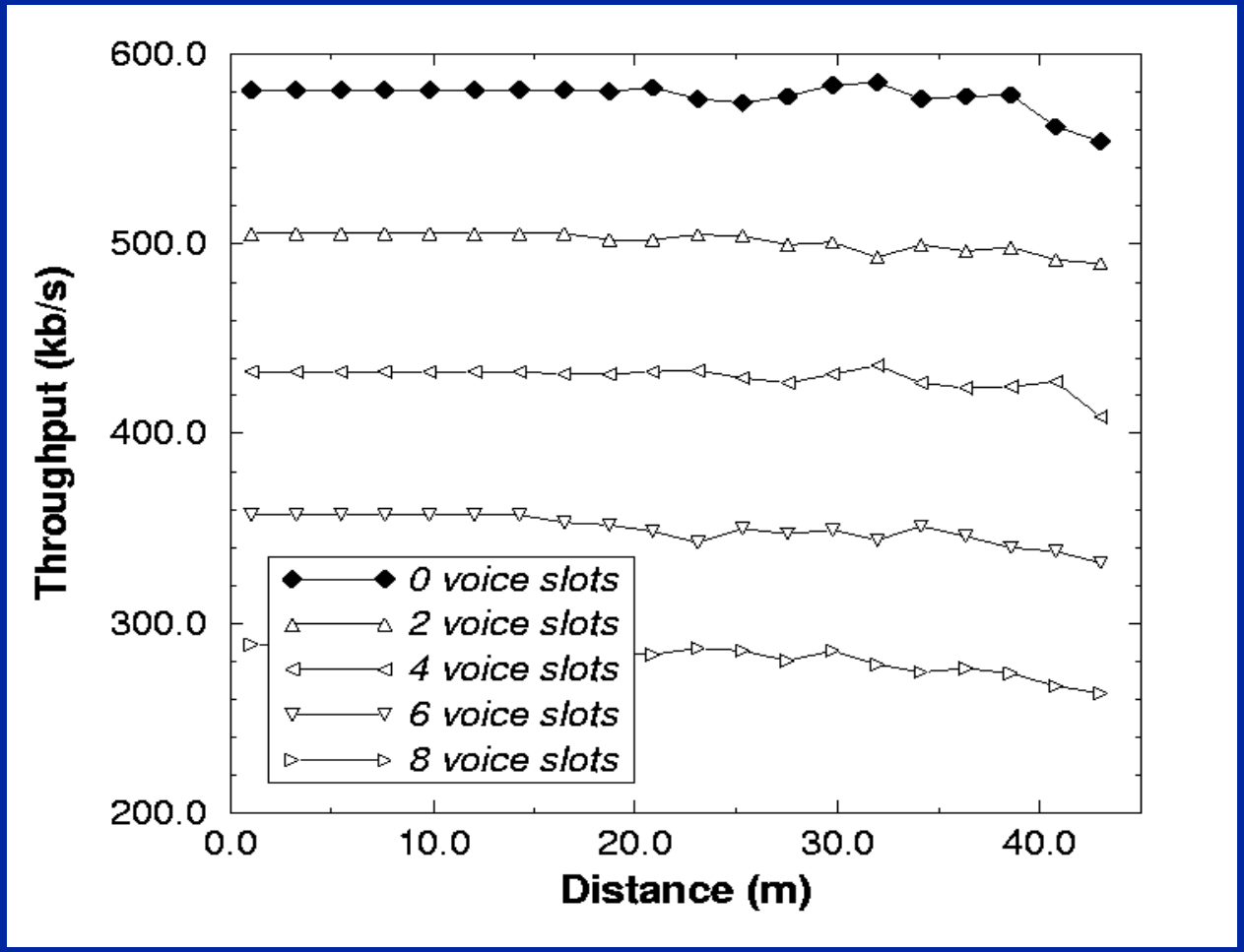
Voice Traffic
Packet Failure .vs. Distance - with SWAP



Acceptable packet failure rate = 3%

Source:
Romans &Tourrilhes, PIMRC'98

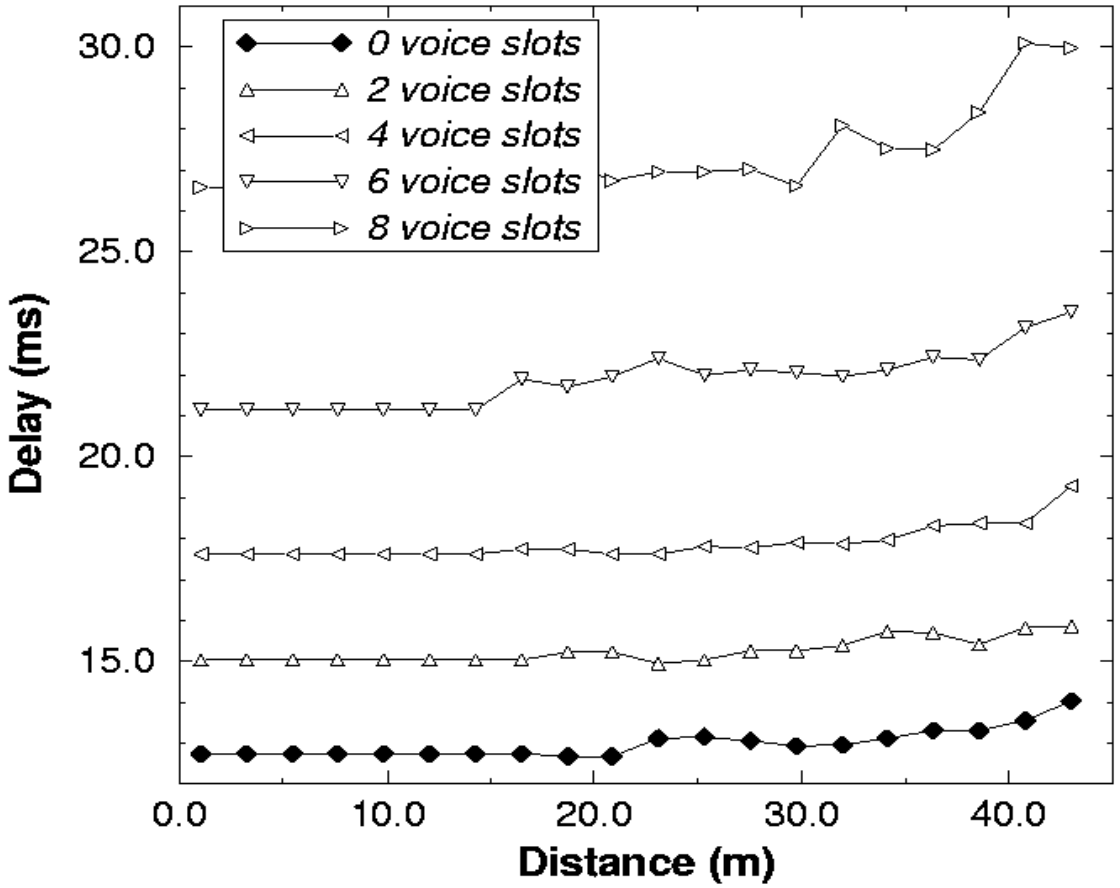
Data Traffic
Maximum Throughput .vs. Distance



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

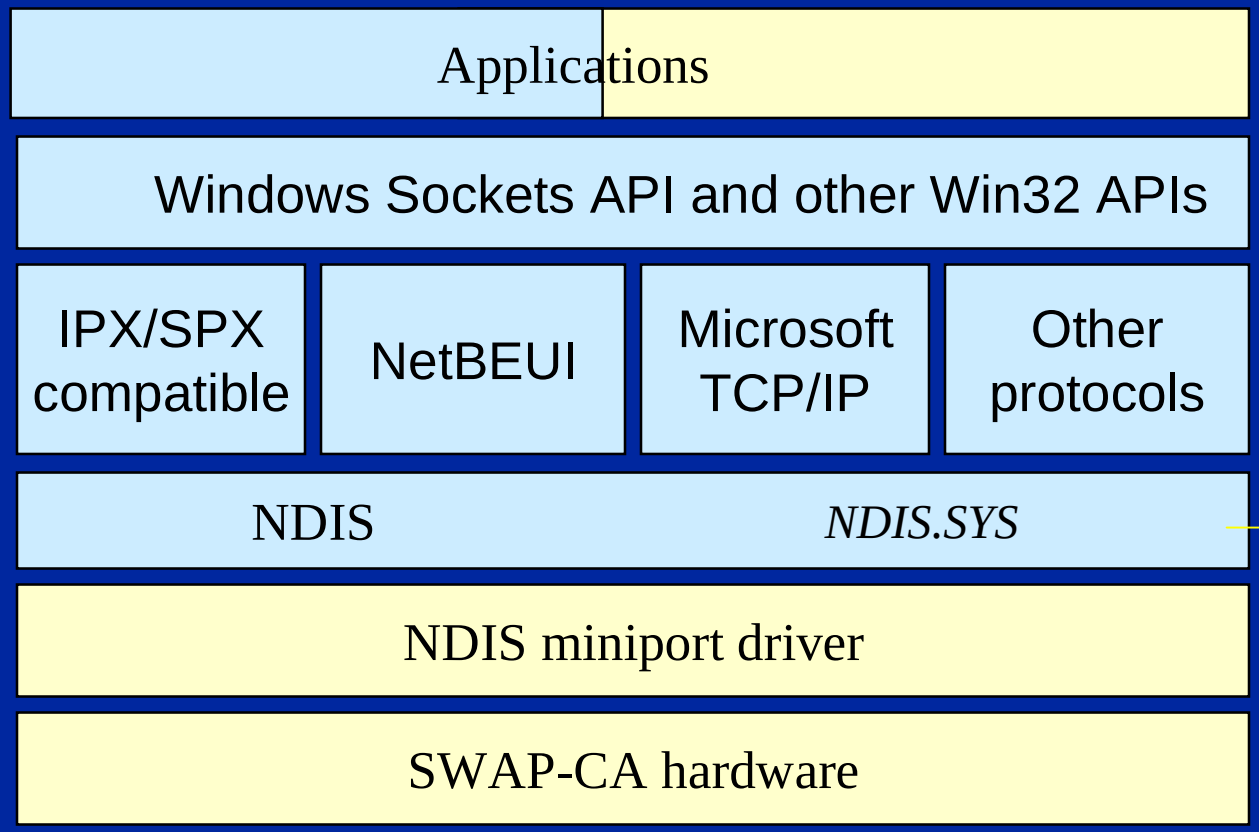
Data Traffic
Average Network Delay vs Distance



Source:
Romans &Tourrilhes, PIMRC'98

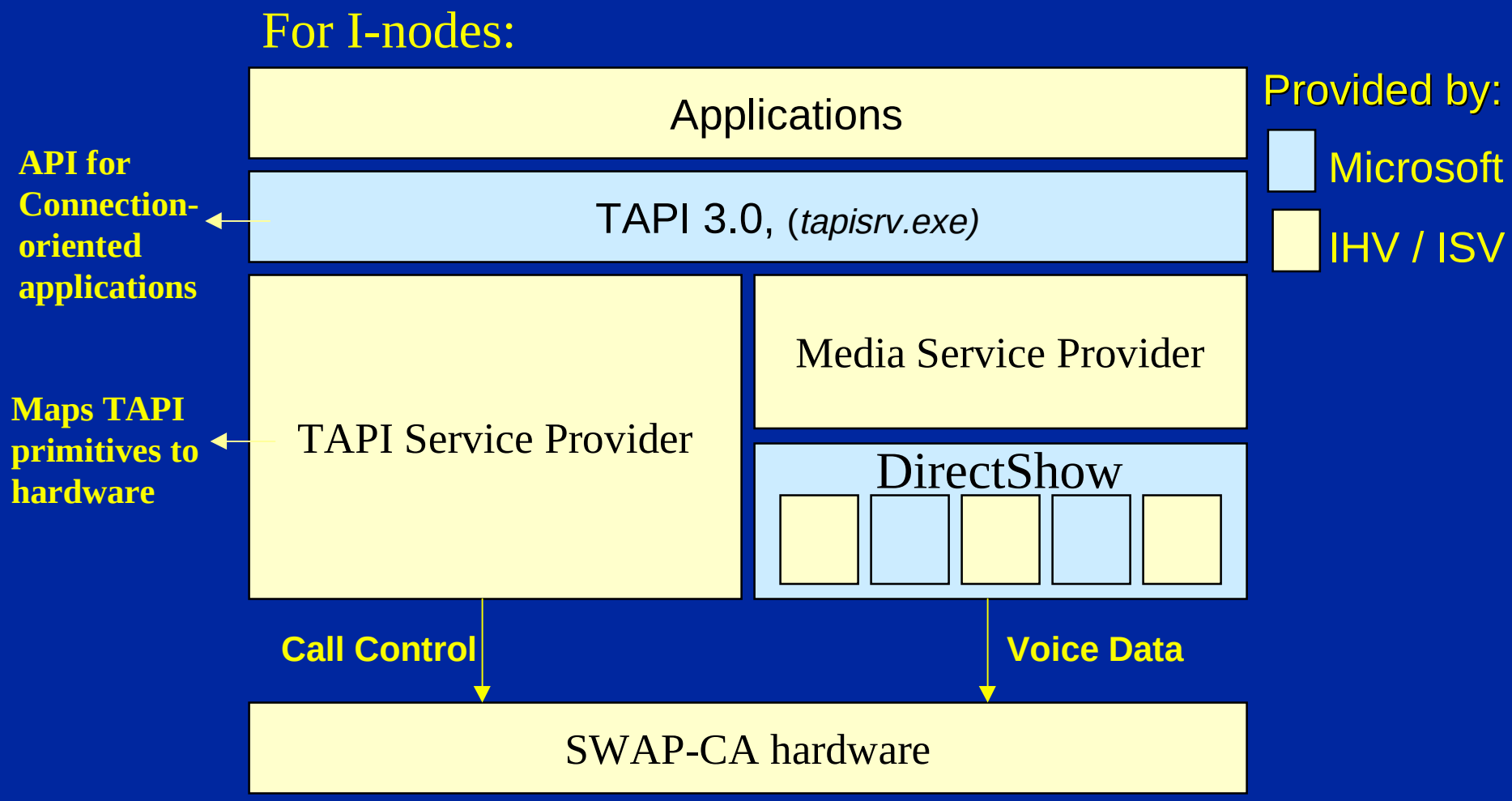
HomeRF™ - Software (MS Windows)

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

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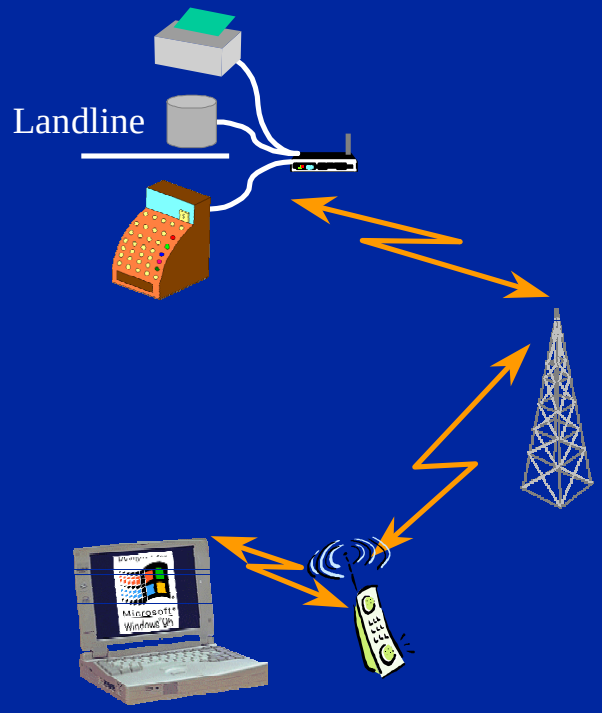
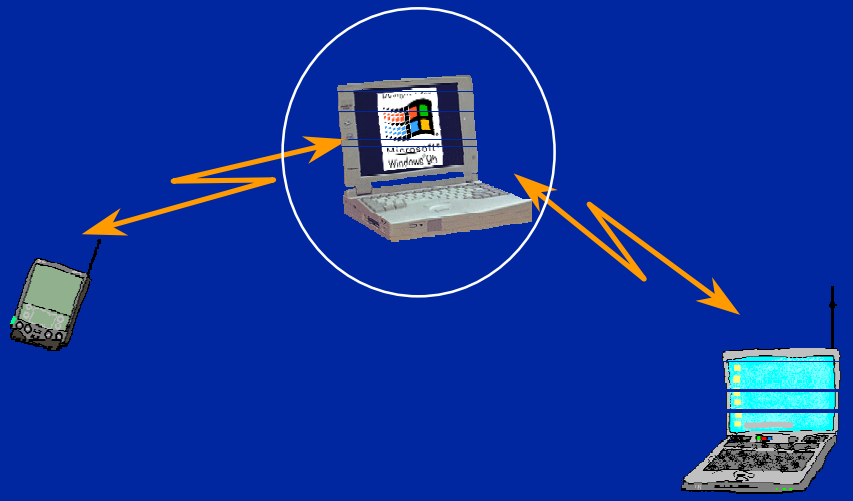
Bluetooth - Vision



Data/Voice Access

Cable Replacement



Personal Ad-hoc Communicators

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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

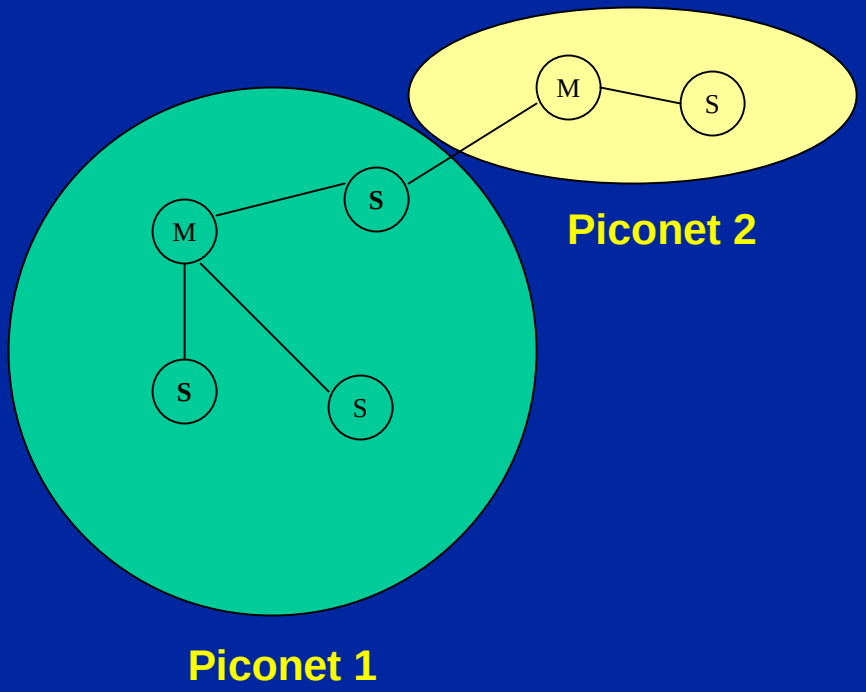
Bluetooth - Design Goals

- 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 simultaneous
  - Each piconet has a unique 48 bit network ID
- Scatternet
  - Radios can share piconets
  - Up to 10 piconets within range



Scatternet

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Comparison

Properties	HomeRF™	Bluetooth	IEEE 802.11
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	?	*- Not specified -*
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	*- Not applicable -*	*- Not applicable -*	*- Not specified -*
Energy Conservation	Yes	Yes	Directory based
Guaranteed Latency	< 20 msec for voice	?	None
Speech Coding	32 Kbps with ADPCM	64 kbps with CVSD / logPCM	*- Not specified -*
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
Enteprise	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