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

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Disclaimer

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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**
- 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

**FUTURE**
- 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

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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

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In the Grand Scheme of Things
Past, Current, and Future

Coverage

Global
Regional
National
Outdoor
Indoor

First Generation

Second Generation

D-AMPS, GSM, IS-95, IS-136

DECT, CT2, PACS, PHS, PWT

Third Generation

FPLMTS
IMT-2000 (ITU-T)
UMTS (ETSI)

HomeRF
IEEE 802.11
HIPERLAN (ETSI)

Year 2002

10 Mbps
100s Kbps
10s Kbps
100s bps
1 Mbps

Speed
+ Broadcast Video
+ Low quality Video
+ Data
Voice
Messaging

10 Mbps
100s Kbps
10s Kbps
100s bps

CDPD, ARDIS, RAM
TACS, AMPS, JMPS, NMT

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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™ - 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.

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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

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

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

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

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

Power management + Channel management

CSMA node (power management) only

Cordless Telephone

Pad

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**HomeRFTM - Operational Modes**

Peer-to-Peer Networking
Ad-Hoc Networking

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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

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HomeRF™ - MAC (SWAP-CA)

TDMA Access

Downlink Slots

Control Point Beacon (CPB)

Service Slot

Contention period

CSMA/CA access mechanism

Voice Slot Transmission

Retransmission Node #3

Uplink Slots

Reception

deletion

Conflict

Header 1

DECT A field

2x DECT B field

CRC

DECT Stack mandated above the MAC

20 bytes

56 bits

640 bits

4 bytes

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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

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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

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Device #1 wakes-up, doesn’t hear a ‘wakeup’, switches itself off

CP sends ‘wakeup’ flag with Device #1’s address

Device #1 wakes-up, hears a ‘wakeup’, stays on

Device #4 asks CP to ‘wakeup’ Device #1

Device #4 hears Device #1 wake-up

Device #1 switches off after timeout

Device #4 and Device #1 exchange data

Device #4 and Device #1 exchange data

Unicast message

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Device #4 wakes up to receive broadcast messages.

Device #4 wakes up to check ‘dwell-to-wakeup’.

Control Point buffers broadcast packets.

Device #4 wakes up to receive broadcast from #1 and #2.

Control Point re-broadcasts messages.

Broadcast messaging:

- Device #1
- Device #2
- Device #4

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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

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Voice Traffic
Packet Failure vs. Distance - with SWAP

Acceptable packet failure rate = 3%

Source:
Romans & Tourrilhes, PIMRC’98
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:

- Applications
- Windows Sockets API and other Win32 APIs
- IPX/SPX compatible
- NetBEUI
- Microsoft TCP/IP
- Other protocols
- NDIS
- NDIS.SYS
- NDIS miniport driver
- SWAP-CA hardware

Looks like, behaves live Ethernet!

Provided by:
- Microsoft
- IHV / ISV

Library of driver functions common to all networking drivers

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HomeRF™ - Software (MS Windows)

For I-nodes:

Applications

API for Connection-oriented applications

TAPI 3.0, (tapisrv.exe)

TAPI Service Provider

Maps TAPI primitives to hardware

Media Service Provider

DirectShow

Call Control

Voice Data

SWAP-CA hardware

Provided by:

Microsoft

IHV / ISV

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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”


Harald Blaatand “Bluetooth” II
King of Denmark 940-981

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Bluetooth - Vision

- Cable Replacement
- Data/Voice Access
- 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

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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

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

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## Possible Technology Positioning

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<th>Cable Replacement</th>
<th>Peer-to-peer Networking</th>
<th>Voice-centric Telephony</th>
<th>Voice &amp; Data Networking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterprise</td>
<td>Bluetooth/IrDA</td>
<td>802.11</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Home</td>
<td>Bluetooth/IrDA</td>
<td>HomeRF-data</td>
<td>?</td>
<td>HomeRF-full</td>
</tr>
<tr>
<td>Mobile</td>
<td>Bluetooth/IrDA</td>
<td>?</td>
<td>Cellular</td>
<td>3G</td>
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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
5 Mahmoud Naghshineh (IBM), Bluetooth presentations at MobiCom ‘98 (Dallas) and PIMRC ‘98 (Boston)

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