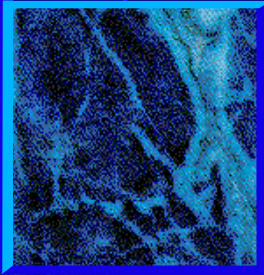


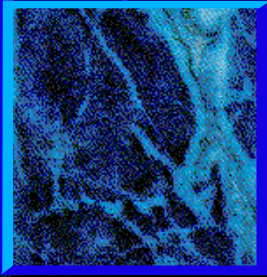
# Bluetooth

Laura Knapp  
ljknapp@us.ibm.com  
1-919-224-2205  
[www.lauraknapp.com](http://www.lauraknapp.com)



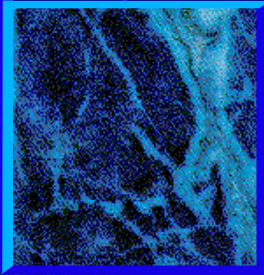
# Agenda

- Marketing Hype
  - ▲ Why Bluetooth
- Usage Models
  - ▲ What Bluetooth can do
- Architecture Overview
  - ▲ How Bluetooth works
- IBM Initiatives
  - ▲ What are IBM's activities?
- Q&A



# Marketing Hype?

Why Bluetooth?



# Bluetooth Background

## What

- Specification for the technology to enable *voice and data* transmission via wireless short-range links
  - ▶ 2.45GHz, within a 10 meters radius extensible up to 100 meters, 1Mbps

## Who

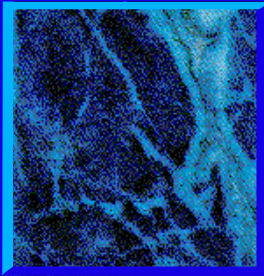
- Ericsson, IBM, Nokia, Intel, Toshiba, (plus > 2000 adopter companies)
- New promoters December 1999: 3Com, Lucent, Microsoft, Motorola
- IBM reps: Peter Lee (PCCo), Brent Miller (PvC), Pravin Bhagwat, Chatshik Bisdikian, Mahmoud Naghshineh, Parviz Kermani (Research), others

## When

- early 98 : 5 companies formed Bluetooth Special Interest Group (SIG)
- 5/20/98 : Announced
- 07/99: Public release of V1.0 specifications for all Bluetooth protocols
- 12/99: Seventh Developers conference, new promoters announcement

## Additional Information

- <http://www.bluetooth.com/>



# Why "Bluetooth"?

Mobile PCs and cellular phones  
should communicate seamlessly.

■ *Harald Blaatand*

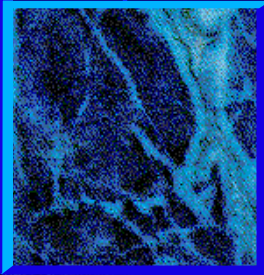
(Bluetooth) II

▲ King of Denmark  
940-981

▲ United Denmark  
and Norway

■ Picture is one of two  
Runic stones in his  
capital city (Jutland, Denmark)





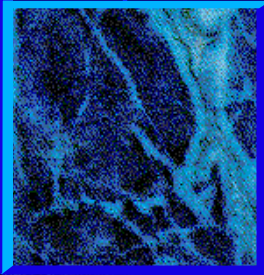
# Mobile Technology Projections

- 33 million mobile computers 2001\*
- 660 million mobile phones 2001\*\*
- Units of new mobile product categories -- unknown
  - ▲ Headsets, PDAs, cameras, access points, ...
- At least 2 devices per user, maybe more
- Bluetooth ramp\*\*\*
  - ▲ 0.5M devices 2000
  - ▲ 60M 2003
  - ▲ 600+M 2005

\* Dataquest, 4/98

\*\* Ericsson Mobile Communications AB, 10/98

\*\*\* Instat/Dataquest 1999



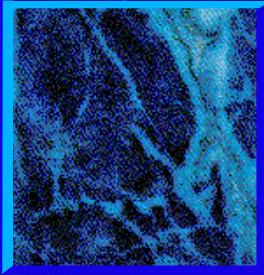
# A New "PC Revolution"



“Mobile computing is changing the whole computer industry.

It’s a revolution that’s likely to be viewed as *more important than the personal computer* in the 80’s.”

- Judy Hamilton, CEO, Dataquest 1994



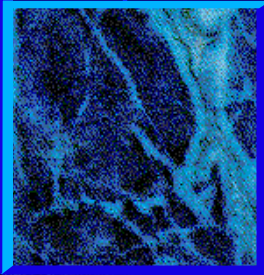
# Mobile Dilemma

All-in-1 device?  
Many devices?



Which devices?  
Which cable  
connectors?

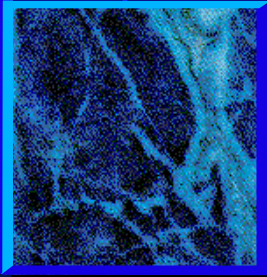




# Bluetooth Solution: Wireless Links Between All Devices

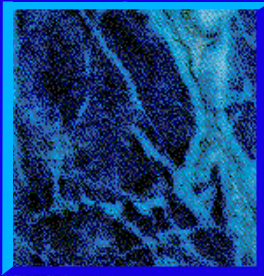
- Major cross-industry initiative
- Revolutionary radio-based solution
- Wireless cable replacement
- Open specification





# Usage Models

What can be done with Bluetooth?



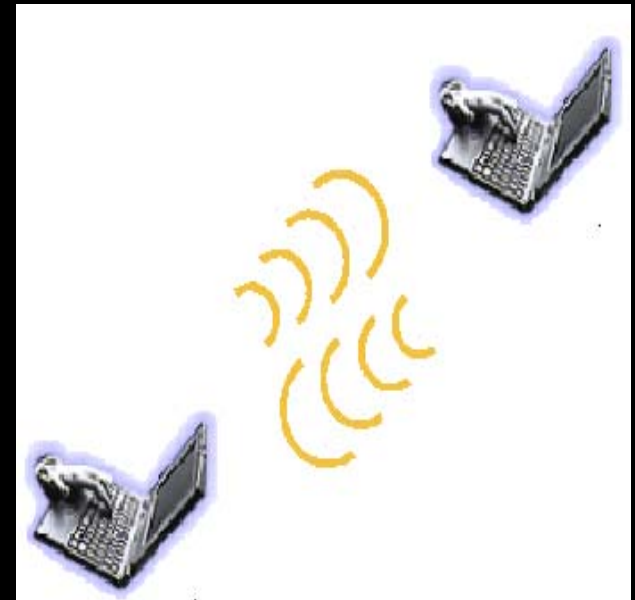
# PC File Transfer

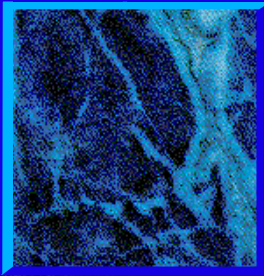
## ■ Scenario

- ▲ Drag-and-drop wireless file transfer between computers
- ▲ Multipoint distribution

## ■ Benefits

- ▲ No cables
- ▲ Anytime, anywhere file sharing
- ▲ No line-of-sight limitation; through walls and briefcases; omnidirectional

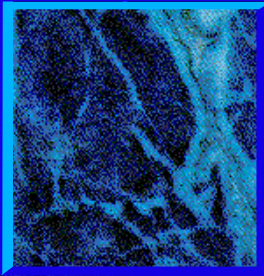




# Dial-Up Networking



- Dial-up networking via cell phone
- Dial through Remote Access Server
- Check email, access Internet
  - ▲ Anytime, anywhere network access without wires
  - ▲ Access to time-critical data
  - ▲ Use existing software; easy TCP/IP integration for networking.



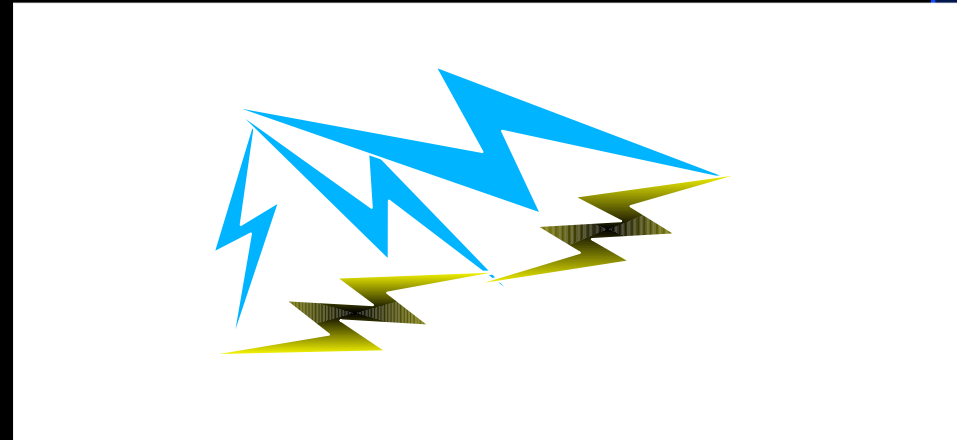
# LAN Access Points/IP Networking

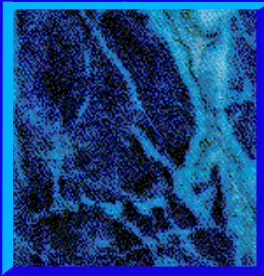
## ■ PPP over RFCOMM

- ▲ In R1.0
- ▲ Interim solution
- ▲ Not user-friendly

## ■ Work underway

- ▲ Ethernet over L2CAP
- ▲ IP over L2CAP
- ▲ Ad-hoc networking, intericonet bridging, etc.

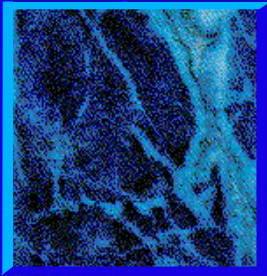




# Synchronizer



- On-demand sync of PDAs, cellular phones, notebooks
- Using existing applications
- Benefits
  - ▲ Data backup
  - ▲ Automated synchronization possible
  - ▲ Seamless, wireless
  - ▲ Device flexibility



# Cordless Computer

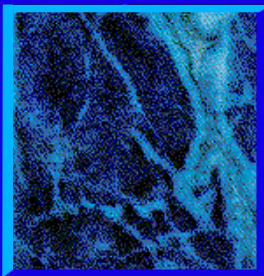
## ■ Wirelessly connected computer peripherals

- ▲ Keyboard
- ▲ Mouse
- ▲ Serial/parallel interfaces
- ▲ Printer
- ▲ Projector
- ▲ etc.

## ■ Benefits:

- ▲ Physical separation
- ▲ Device sharing

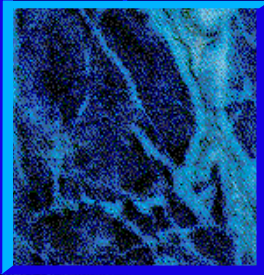




# Ultimate Headset



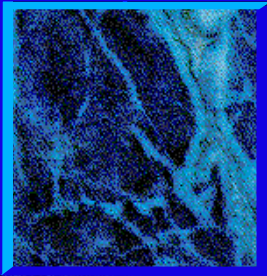
- **Wireless headset for phone and computer**
- **Phone Peripheral**
  - ▲ Place call on cellphone, talk on headset
- **Mobile PC/Cordless Phone**
  - ▲ Place call on PC, talk over POTS line via headset
- **Benefits**
  - ▲ Convenience
  - ▲ Mobility
  - ▲ Voice dictation



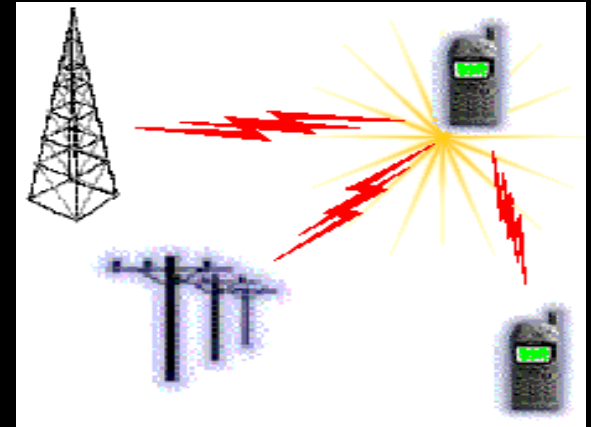
# Computer SpeakerPhone

- Phone audio is routed to and from the mobile PC's speakers and microphone
- Dial from phone or PC
- Benefits:
  - ▲ Instant conference calling
  - ▲ Increased mobility

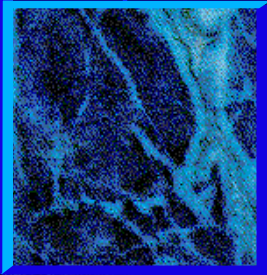




# 3-in-1 Phone



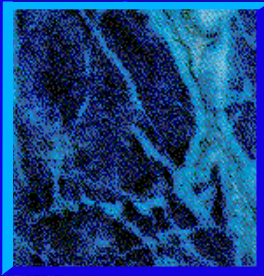
- Multifunction phone with intercom, cordless and cellular abilities
- Features
  - ▲ On-the-road cellular phone
  - ▲ Carrierless phone-to-phone calling
  - ▲ Cordless phone
- Benefits:
  - ▲ Single handset, single phone number
  - ▲ Reduced air time charges



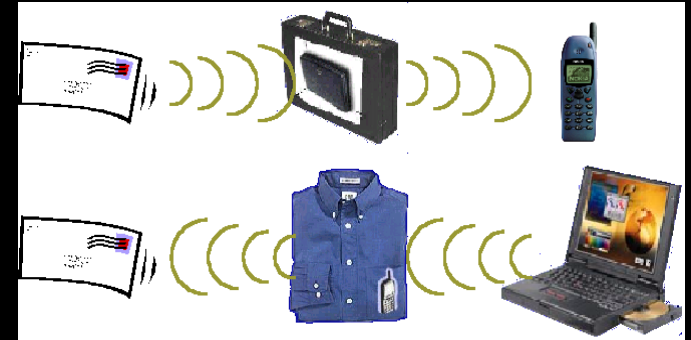
# Instant Postcard

- Transfer digital camera images to PC or cell phone
- Benefits:
  - ▲ Increased storage capacity
  - ▲ Real-time documentation
  - ▲ No wires





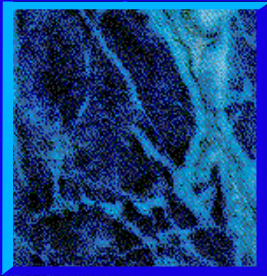
# Hidden Computing



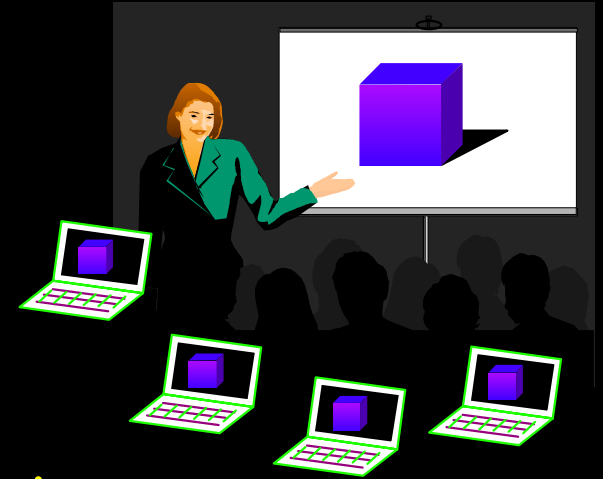
- Communicating apps function without user interaction, based on user-defined policies

- ▲ Phone/PDA controls computer system
- ▲ Phone alerts user of incoming email
- ▲ Email forwarding to phone
- ▲ Text-to-speech email playback
- ▲ Speech-controlled application





# Conference Table

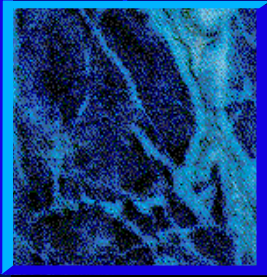


## ■ Wireless support for ad-hoc collaborative groupware applications

- ▲ Business card exchange
- ▲ Whiteboard
- ▲ Chat
- ▲ File sharing, co-editing
- ▲ Wireless projector
- ▲ Meeting management/follow-up scheduling

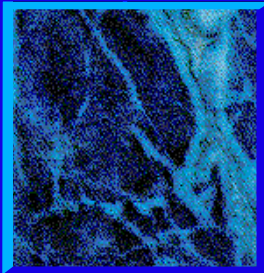
## ■ Benefits

- ▲ In-room or remote participants
- ▲ Everybody gets a copy of the data
- ▲ Paperless meeting



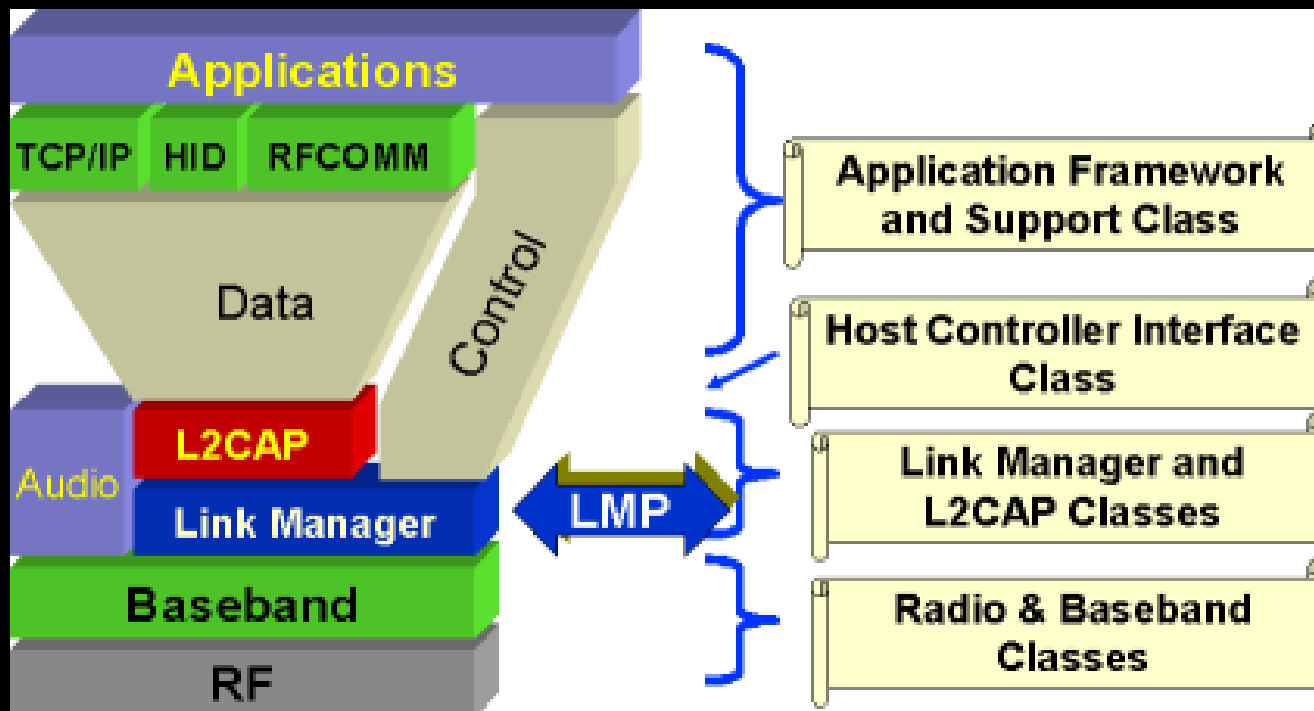
# Architecture Overview

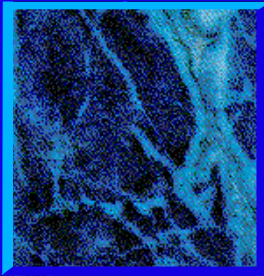
How does Bluetooth work?



# What is Bluetooth?

- A hardware description
- An application framework





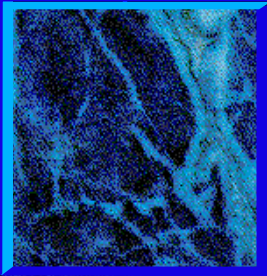
# International 2.4 GHz ISM Band

## ■ Requirements

- ▲ Channel BW limited to 1 MHz
- ▲ Spectrum spreading must be employed
- ▲ Multiple uncoordinated networks may exist, and cause interference
- ▲ Band shared with microwave ovens
- ▲ 2.4 GHz chips operate at high current

## ■ Bluetooth Solution

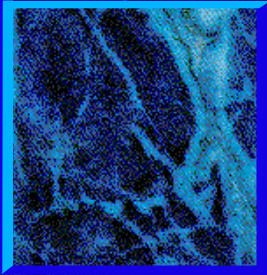
- ▲ 1 Mb/s symbol rate exploits maximum channel B/W
- ▲ Fast freq.hopping and short packets avoid interference
- ▲ CVSD voice coding tolerates high error rates
- ▲ Air interface minimizes current consumption
- ▲ Low-cost single-chip integration



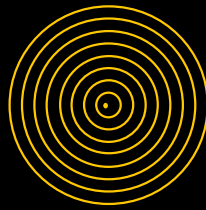
# Globalization



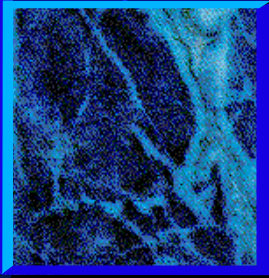
- Single version worldwide
  - ▲ 2.4GHz spectrum unlicensed globally
- Complies with global radio emission rules
- Working through FCC, EC, Japan for spectrum and power harmonization
- Safe for in-flight use
  - ▲ But not yet approved for in-flight use
- Working with FAA, FCC, plane manufacturers, airlines for avionics compatibility



# Bluetooth vs. Wires

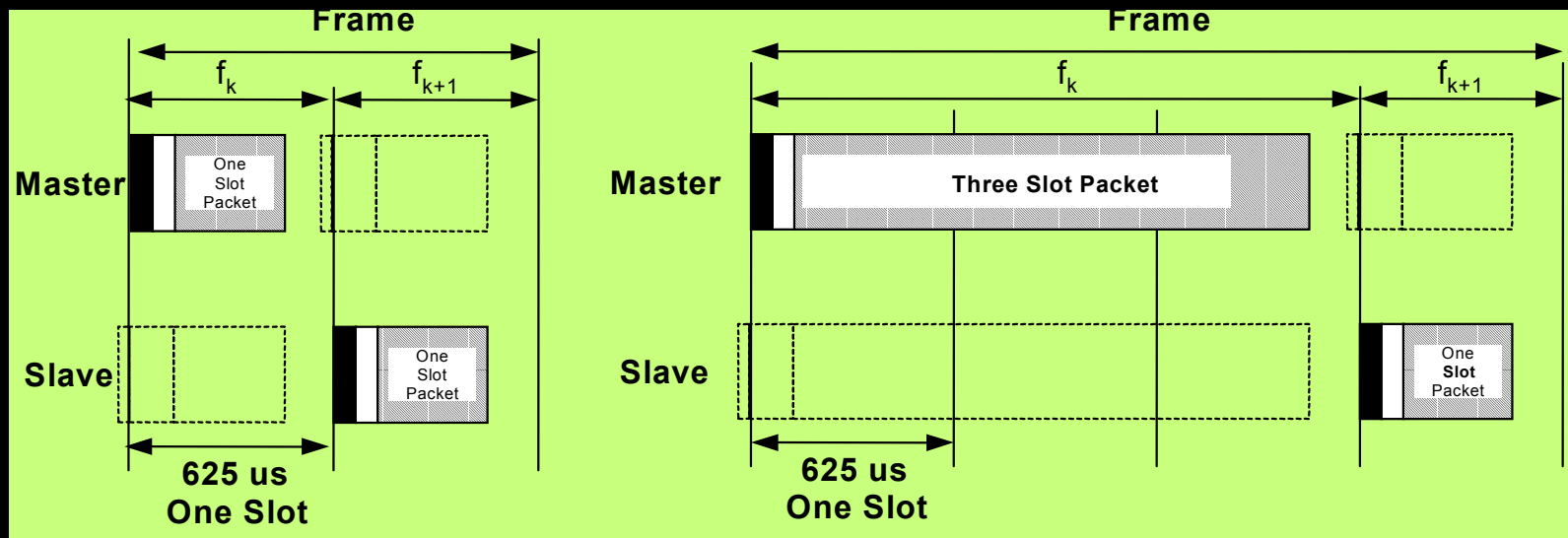


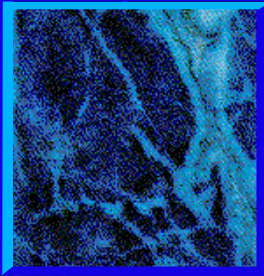
<b>Topology</b>	Up to 7 simultaneous links	One cable per link
<b>Flexibility</b>	Goes thru walls, bodies, clothes...	Line-of-sight or modified environment
<b>Data rate</b>	1 MSPS, 720 Kbps	Varies with use and cost
<b>Power</b>	0.1 watts active power	0.05 watts active power or higher
<b>Size/Weight</b>	25 mm x 13 mm x 2 mm, several grams	Range = cable length. Typically 1-2 meters. Weight varies with length (ounces to pounds)
<b>Cost</b>	Long-term \$5 per endpoint	~ \$3-\$100/meter (end user cost)
<b>Range</b>	10 meters or less Up to 100 meters with PA	Range equal to size. Typically 1-2 meters
<b>Universal</b>	Intended to work anywhere in the world	Cables vary with local customs
<b>Security</b>	Very – link layer security, SS radio	Secure (it's a cable)



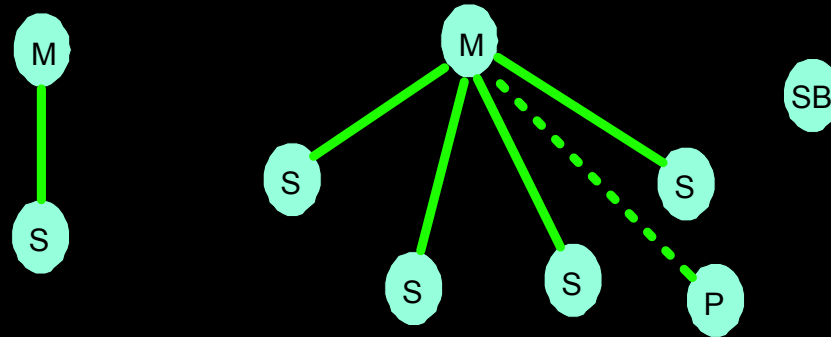
# Baseband Protocol

- Spread-spectrum frequency-hopping radio
  - ▲ 79 [23] one-MHz channels in 2.4 GHz ISM band
  - ▲ 1600 slots per second
  - ▲ Frequency hops every packet (1, 3, or 5 slots)
  - ▲ Frame = 1 transmit + 1 receive packet, back-to-back





# Piconet Topologies

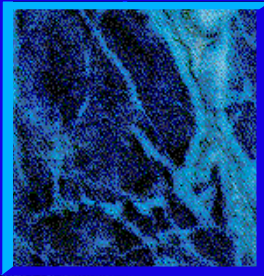


## ■ Connected radios can be master or slave

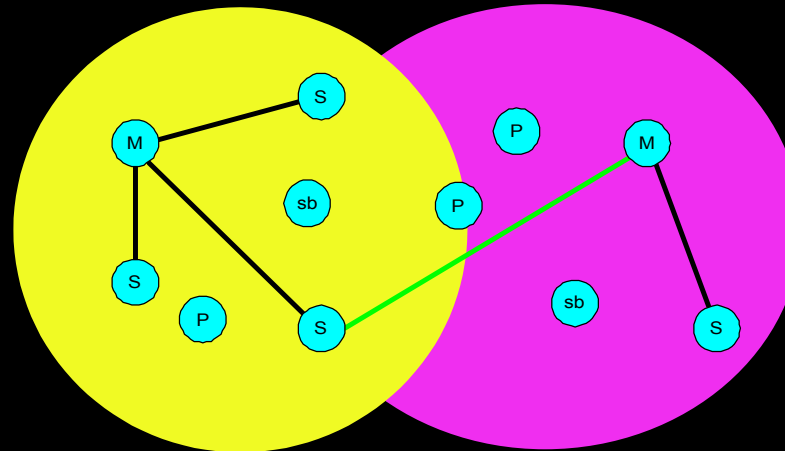
- ▲ Any device can assume either role
- ▲ Each device has unique 48 bit address

## ■ Piconet < 1 Mbps

- ▲ 1 Master can connect 7 simultaneous or 255 parked slaves per piconet
- ▲ Master sets clock and hopping pattern
  - 723.2 Kbps data or 3 voice channels
- ▲ Slaves can communicate only via master

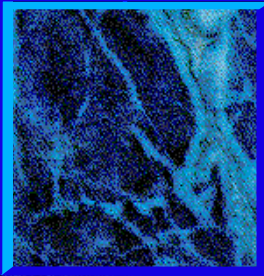


# Scatternet Topology



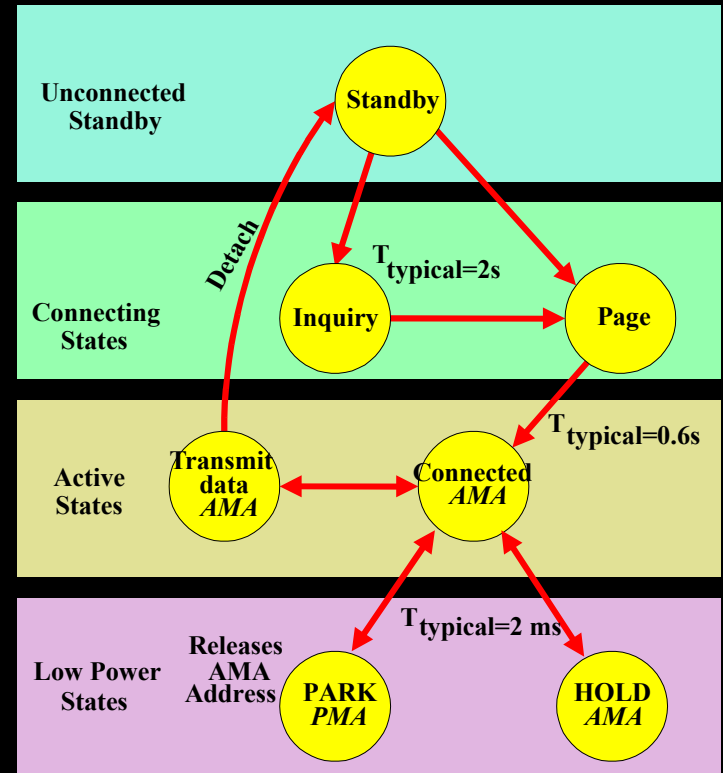
## ■ Scatternet

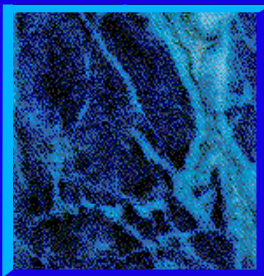
- ▲ Multiple co-located piconets (sharing of common master or slave devices)
- ▲ Up to 10 piconets with minimal collision



# Baseband States















- **Standby** - Waiting to join a piconet
- **Inquire** - What radios can I connect to?
- **Page** - Connect to a specific radio
- **Connected** - Actively in piconet, as Master or Slave
- **Park/Hold** - Low-power connected states

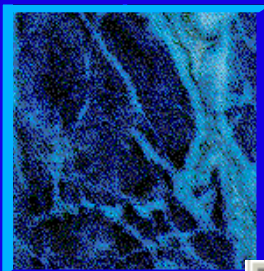




# Discovery Panel



Local Services	Name	Class	Status	Bonding	Role
 Audio	My Inbox				
 My Shared Files					
 Conference		Device Folder			
	00:50:CD:00:00:33	Laptop	Last seen: 01-08...	Not bonded	
	00:50:CD:00:00:3F	Miscellaneous	Connected	Not bonded	Slave
	00:50:CD:00:00:80	Miscellaneous	Last seen: 02-08...	Not bonded	
	00:50:CD:00:00:84	Miscellaneous	Last seen: 02-08...	Not bonded	
	00:50:CD:00:30:4F	Miscellaneous	In range	Not bonded	
	00:50:CD:10:00:0D	Miscellaneous	Last seen: 03-08...	Not bonded	
	00:50:CD:10:00:6A	Miscellaneous	Last seen: 02-08...	Not bonded	
	Bluetooth Client D...	Desktop Workst...	Last seen: 03-08...	Not bonded	
 DUN	Eddie's Notepad	Laptop	Last seen: 01-08...	Not bonded	
 FAX	Niels' Laptop	Laptop	In range	Not bonded	
					



# Data Transfer

The screenshot shows a Windows XP file explorer window titled "W. Singer TP A21M". The address bar contains "W. Singer TP A21M". The main pane displays icons for "Business Card", "Inbox", "Network", and "Shared Files". A "Pushing objects" dialog box is open in the foreground, showing a progress bar and the text "Pushing blueugde.pdf to W. Singer TP A21M". The status bar at the bottom indicates "Local Device Name: Singer1" and shows transfer speeds: "Tx: 32,1 KB/Sec" and "Rx: 0,0 KB/Sec".

W. Singer TP A21M

Datei Bearbeiten Ansicht Favoriten Extras Bluetooth ?

Adresse W. Singer TP A21M Wechseln zu Links >>

Local Services

Local Profiles

Dial-up Networking

Ethernet Network

Fax

Business Card

Inbox

Network

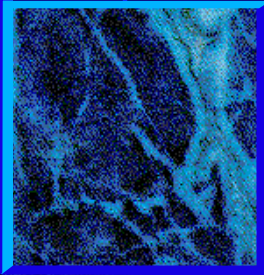
Shared Files

Pushing objects

Pushing blueugde.pdf to W. Singer TP A21M

Cancel

W. Singer TP A21M Local Device Name: Singer1 Tx: 32,1 KB/Sec Rx: 0,0 KB/Sec



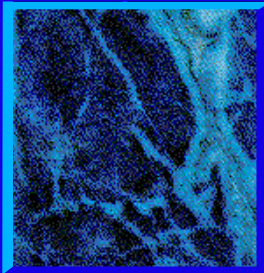
# Baseband Link Types (PHY layer)

## ■ Synchronous Connection-Oriented (SCO)

- ▲ Circuit switching
- ▲ Symmetric, synchronous services
- ▲ Slot reservation at fixed intervals

## ■ Asynchronous ConnectionLess (ACL)

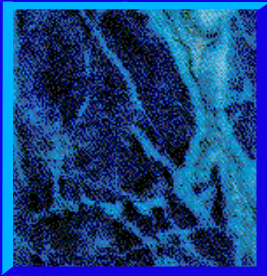
- ▲ Packet switching
- ▲ Asymmetric, asynchronous services
- ▲ Polled access scheme



# Battery Life



- Protocols designed specifically for battery-operated mobile devices
  - Low power consumption achieved by
    - ▲ Programmable data length
    - ▲ Sleeping when no work scheduled
    - ▲ Adaptive use of minimum transmitter power
  - Estimates
    - ▲ Voice (SCO)                      8-30 mA                      ~ 75 hrs.
    - ▲ Data (ACL)                        avg. 5 mA                    ~120 hrs.
    - ▲ Standby                            < 0.3 mA                    ~ 3 mo.
    - ▲ Hold and park modes        ~ 60  $\mu$ A
- \*Calculated with 600 mAh battery and internal amp, varies with implementation



# Adaptive Radio Range



## ■ Two types

- ▲ 0 dBm - 10 meters (r1.0)

- ▲ 20 dBm - 100 meters

## ■ *Integral Received Signal*

### *Strength Indicator*

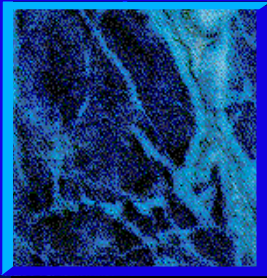
- ▲ Limit radio power to minimum necessary

- ▲ Reduce power consumption

- ▲ Reduce interference

  - potential problems with 802.11b

- ▲ Maximize spatial reuse

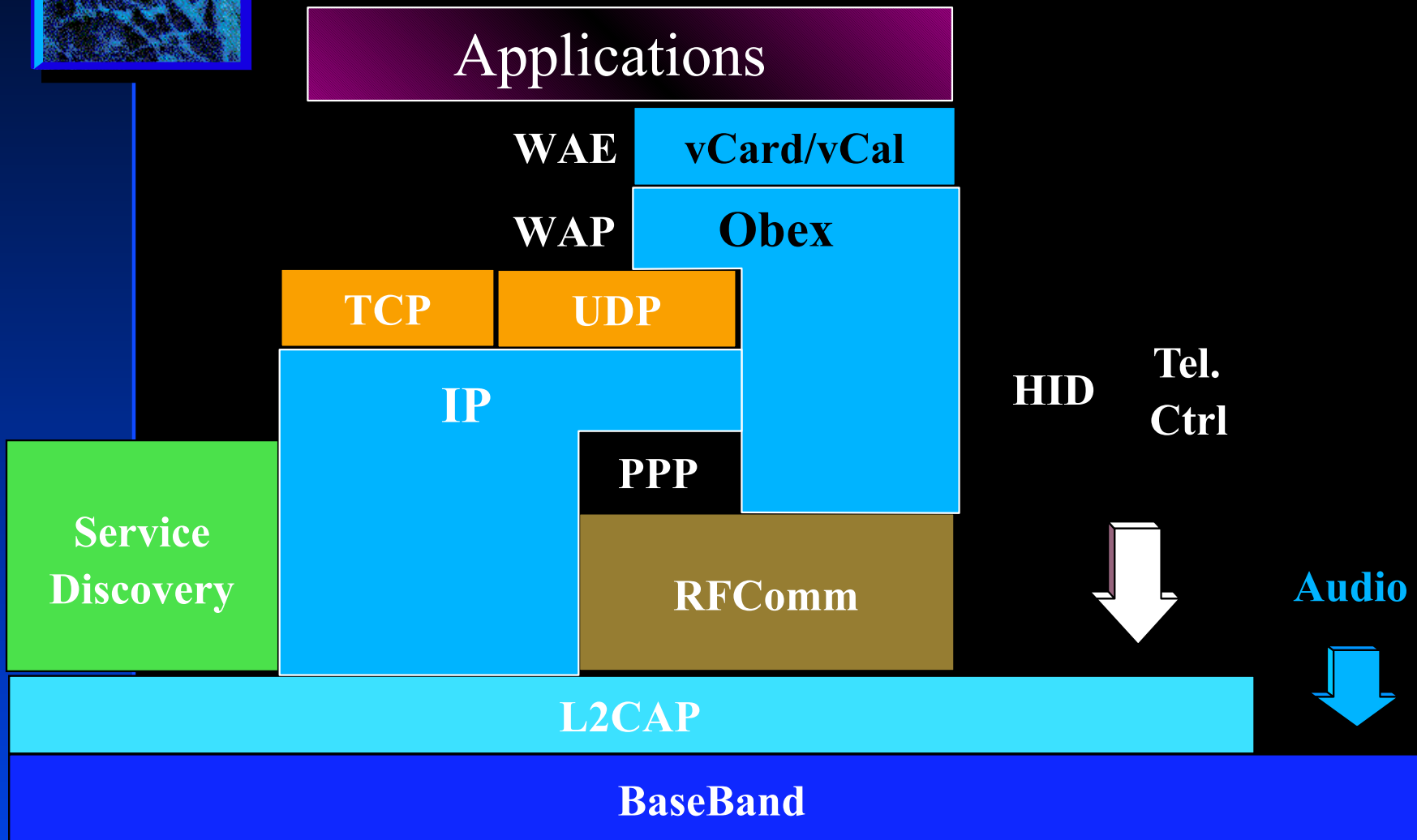


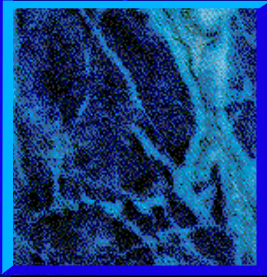
# Baseband Security



- Extremely difficult to eavesdrop (frequency-hopping)
- Authentication
  - ▲ 128-bit key, E1 algorithm
  - ▲ Challenge/response
- Encryption
  - ▲ Variable key length
    - ▲ Comply with government export regulations
  - ▲ Stream cipher
  - ▲ E0 algorithm
- Key management and generation
- Security policy architecture white paper on web site

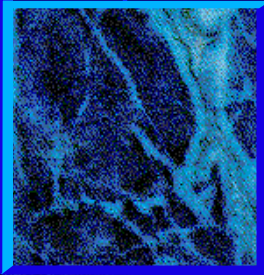
# Protocol Hierarchy





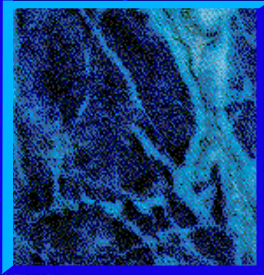
# **IBM Bluetooth Initiatives**

**What are IBM's activities?**



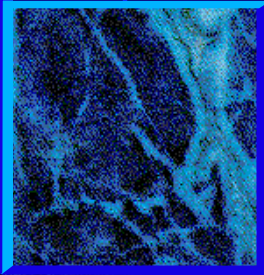
# Bluetooth: IBM's Role and Status

- IBM is a founding member
  - ▲ Holds seat on Program Management Committee
- IBM has set technical direction in several areas
  - ▲ IBM chaired Service Discovery Protocol task force
  - ▲ Significant contributions in air/baseband protocols, networking over Bluetooth, hidden/unconscious computing, lower layer protocols, security
- Standard Programming Interfaces
  - ▲ air/baseband
  - ▲ networking
  - ▲ service discovery protocol



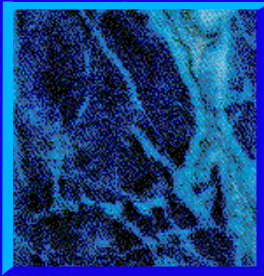
# General SIG Status

- All Software Specifications Ratified
  - ▲ Released July 1999
- All major Profiles complete for R1.0
  - ▲ Cover R1.0 usage cases
  - ▲ Promote interoperability
- R1.0 Errata Complete
- Over 2000 adopter companies
- "Bluetooth-2" kicked off December 1999



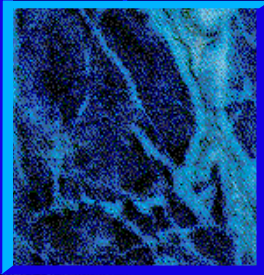
# Recent/Upcoming Bluetooth Events

- Bluetooth "SIG-2" Kicked off
  - ▲ Printing Profile
  - ▲ Multimedia Profile
  - ▲ Automotive Profile
  - ▲ etc.
- Developers Conference June 1999, London
  - ▲ IBM speakers included Peter Lee, Chatschik Bisdikian, Brent Miller
- Bluetooth Australia, February '01, Sydney
- Bluetooth Conference March '01, Guangzhou
- Bluetooth Conference March '01, Tokyo
- Bluetooth Conference March '01, Toronto
- Bluetooth Congress June '01, Monaco



# IBM Bluetooth Directions

- Ensure open standard, level playing field
  - ▲ Open protocol specifications
- Coexistence with/accomodation for important technologies
  - ▲ Networking standards (TCP/UDP/IP)
  - ▲ Java™
  - ▲ WAP
  - ▲ Service Discovery  
(Jini™, UPnP™, SLP, Salutation™)
- Cross-platform Bluetooth implementations
  - ▲ Hardware and Software



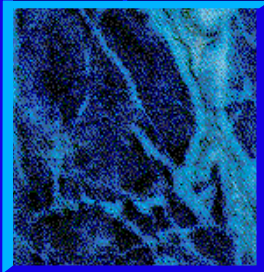
# IBM Bluetooth Directions

## ■ Develop/Deploy IBM assets in pervasive computing domain

- ▲ Bluetooth technology
- ▲ PvC client software
- ▲ Networking middleware
  - ▲ Scalability
  - ▲ Security
  - ▲ etc.
- ▲ Speech technology

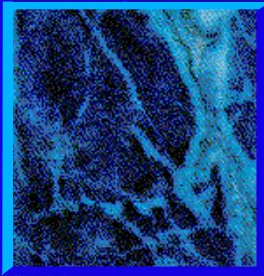
## ■ Products/Technology

- ▲ i Series ThinkPad, Bluetooth PC Card 4Q '00
- ▲ "BlueDrekar" software, IBM alphaWorks



# Other Potential Products

- Car enhancements
  - ▲ seat adjustments, mirrors, temperature
  - ▲ motor management, theft control, tire pressure
- Garage and home door opener
  - ▲ security/control systems, home appliances
- Syncing and offloading (e.g. cameras) to IBM microdrive
- Text recognition pen
- Sticker to convert IR to Bluetooth
  - ▲ e.g. for PCs, TVs, remote controls

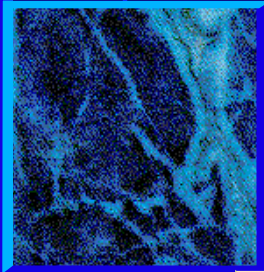


# IBM Bluetooth Products

PCMCIA card  
\$189 Web price  
part number: 09N9812  
available: Oct. 2000



Bluetooth Ultraport for Thinkpads, 3Q2001  
Palmpilot/Workpad Bluetooth options, 3Q2001  
more to come... stay tuned



# Potential Collaboration Areas

## ■ IBM/companyX might collaborate in:

### ▲ End-to-End solutions

- ▲ WAP/Bluetooth coexistence
- ▲ Merging of voice and data communications
- ▲ Network access from telephony devices
- ▲ Middleware and backend server software for Bluetooth voice and data network access points
- ▲ IBM Transcoding technology

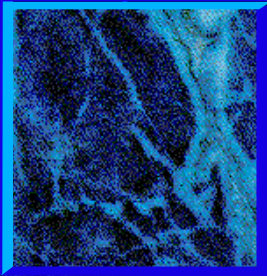
### ▲ Mobile e-commerce

- ▲ IBM white paper has several examples

### ▲ Others?

- ▲ The above are initial thoughts

# Resources



## ■ Bluetooth SIG

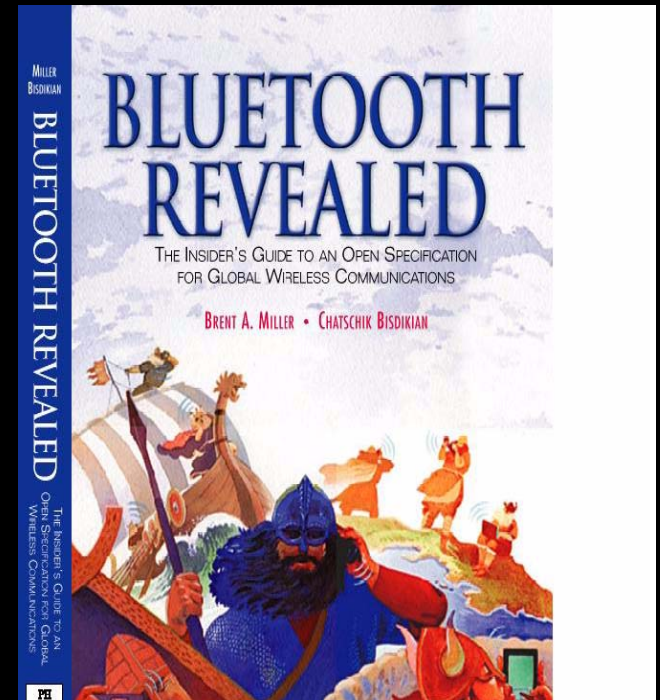
▲ <http://www.bluetooth.com>

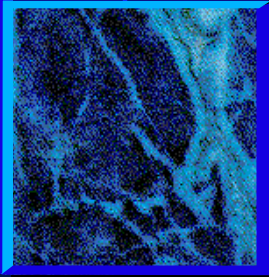
## ■ Pervasive Computing

▲ <http://www.ibm.com/pvc>

## ■ External book written by Brent Miller & Co.

▲ *Bluetooth Revealed*, published by Prentice-Hall, September 2000





# Discussion

