Bluetooth

Agenda

- What is Bluetooth?
  - Bluetooth in the home and on the road
  - Overview of Bluetooth devices and applications
  - Bluetooth vs. other wireless LAN technologies
- Inside Bluetooth
  - How it works
- Xilinx opportunities in Bluetooth
  - Immediate opportunities
  - Long term prospects

The Obligatory Bluetooth Question
Where Does the Name Come From?

- Ericsson, the principal inventor, borrowed the name from Harald Bluetooth (son of Gorm)
  - The King of Denmark circa 900AD
  - United Denmark and Norway
- Seemed like a good name for uniting many dissimilar devices from different manufacturers
  - Marketing observation: At least ignoring that the unification didn't last!

Learn your Viking name at:
www.gorm.com/name/index.htm

What is Bluetooth?

- A unique new wireless technology specifically for:
  - Short range
    - Up to 10 meters typically
  - Modest performance (720Kbps)
  - Dynamic configurability
    - i.e. ad hoc networking/roaming
  - Low power
    - Well suited to handheld applications
  - Support for both voice and data

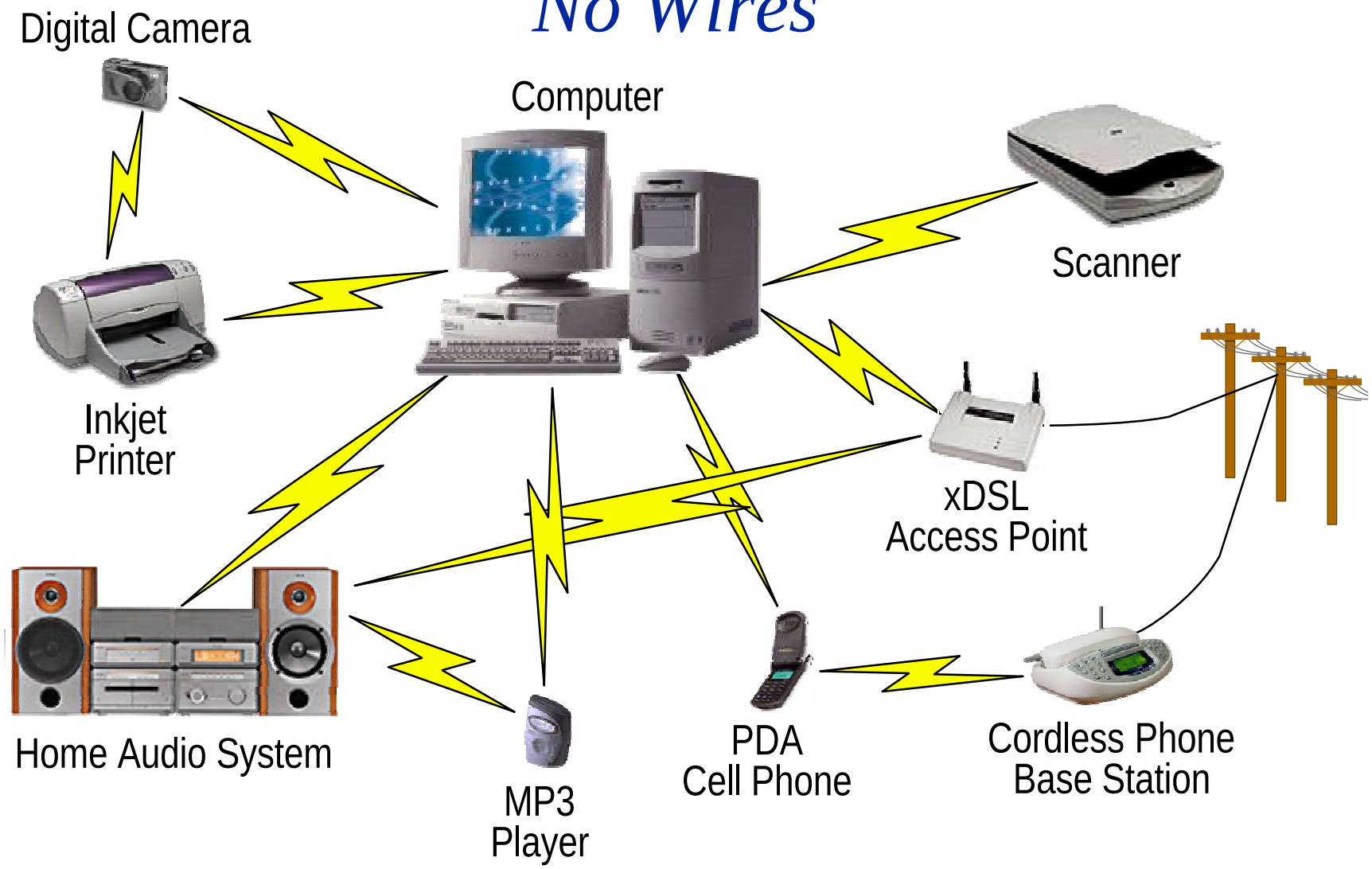
And an *EXPLOSIVE* growth market!!!

What is Bluetooth Good For?

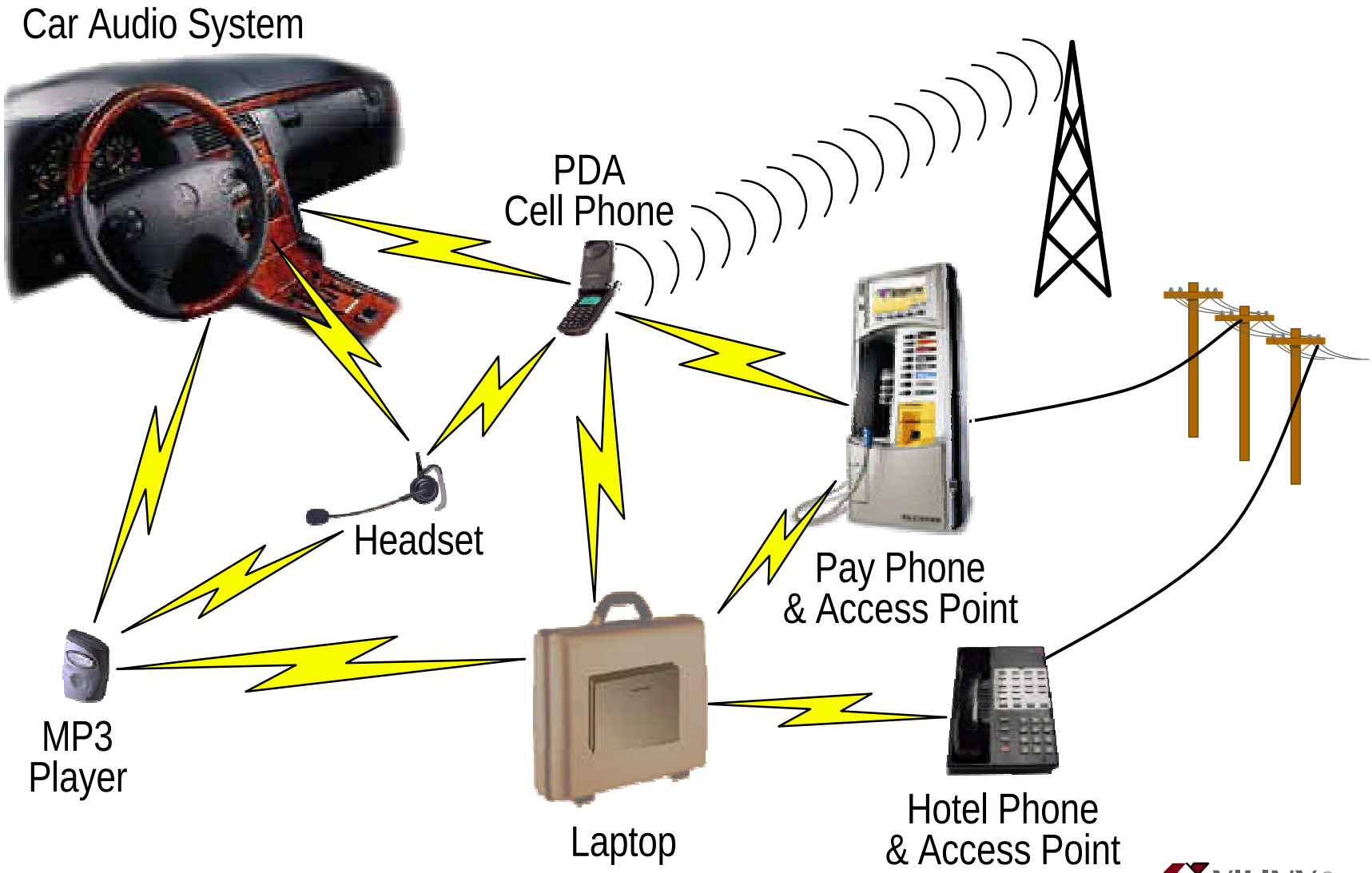
- No Wires!
  - In the home
  - On the move
- Personal Area Networking (PAN)
  - Enabling several personal devices to work together
- Locality sensitive services (i.e. roaming)
  - Visibility and access to additional resources, but only when they are within range and useful to you

Bluetooth in the Home

No Wires



And On the Road



Bluetooth in Computer Products

Computer devices

- Laptop computers

- PDAs/HPCs

- Desktop PCs

- Broadband access points
  - Ethernet/xDSL/cable

- Printers

- Scanners

- Video projectors

- Web tablets

Computer applications

- Peripheral connectivity
  - Printers
  - Scanners
  - Video projectors
- Network access
  - Broadband access points
  - Packet radio cellular phones
- File synchronization
  - Calendars
  - Contact management
- File transfer
  - VCards
  - MP3
  - Digital pictures

Bluetooth in Telephone and Consumer Products

Telephone devices

- Cellular handsets

- Wireless headsets

- PSTN access points
  - Payphones
  - Hotel/home phones

Telephone applications

- Hands free use
- File synchronization
  - Calendars
  - Contact management
- Land line I/F for voice and data

Consumer devices

- Set-top boxes

- Digital cameras

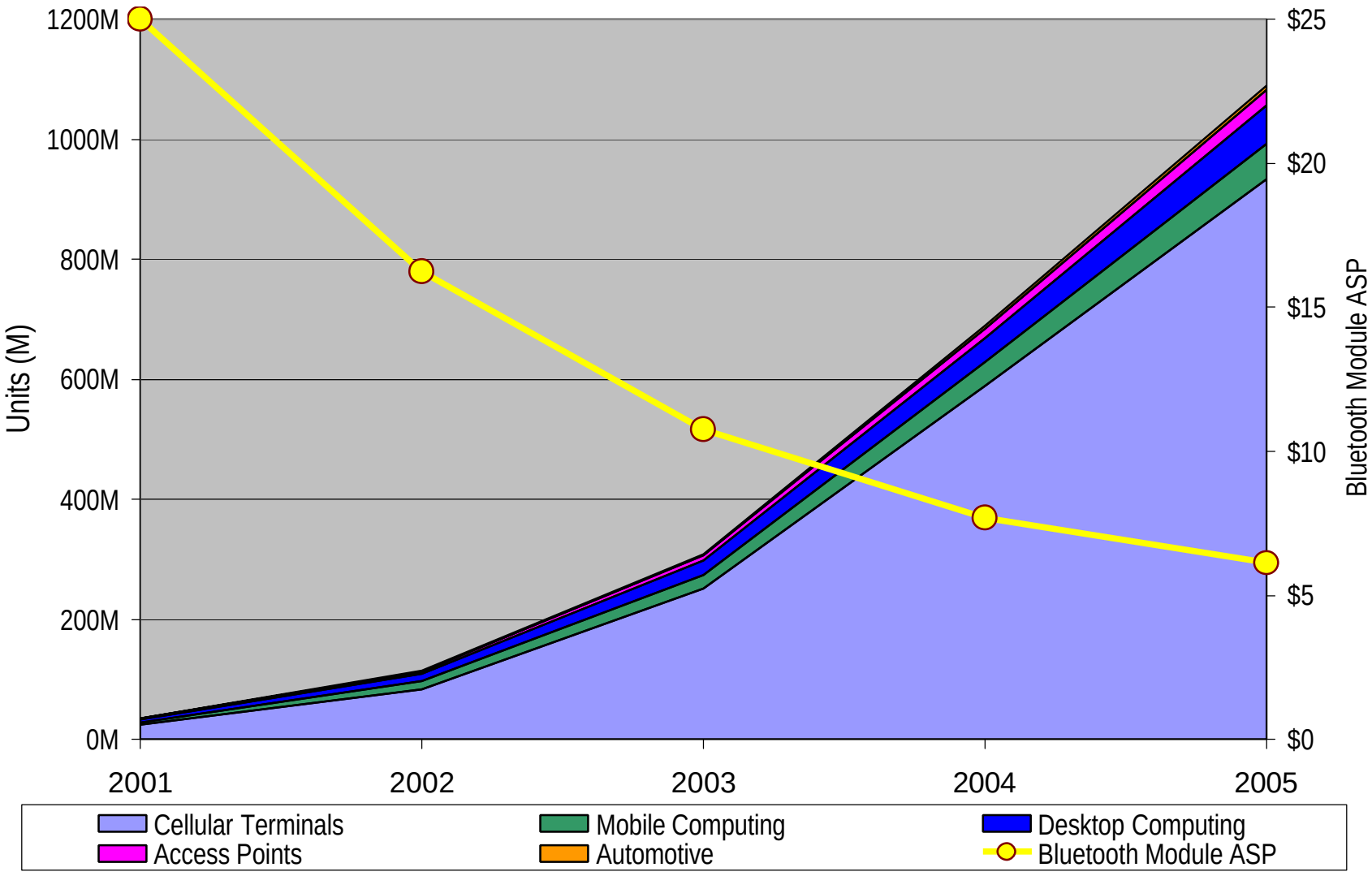
- MP3 audio players

- Home audio systems

Consumer applications

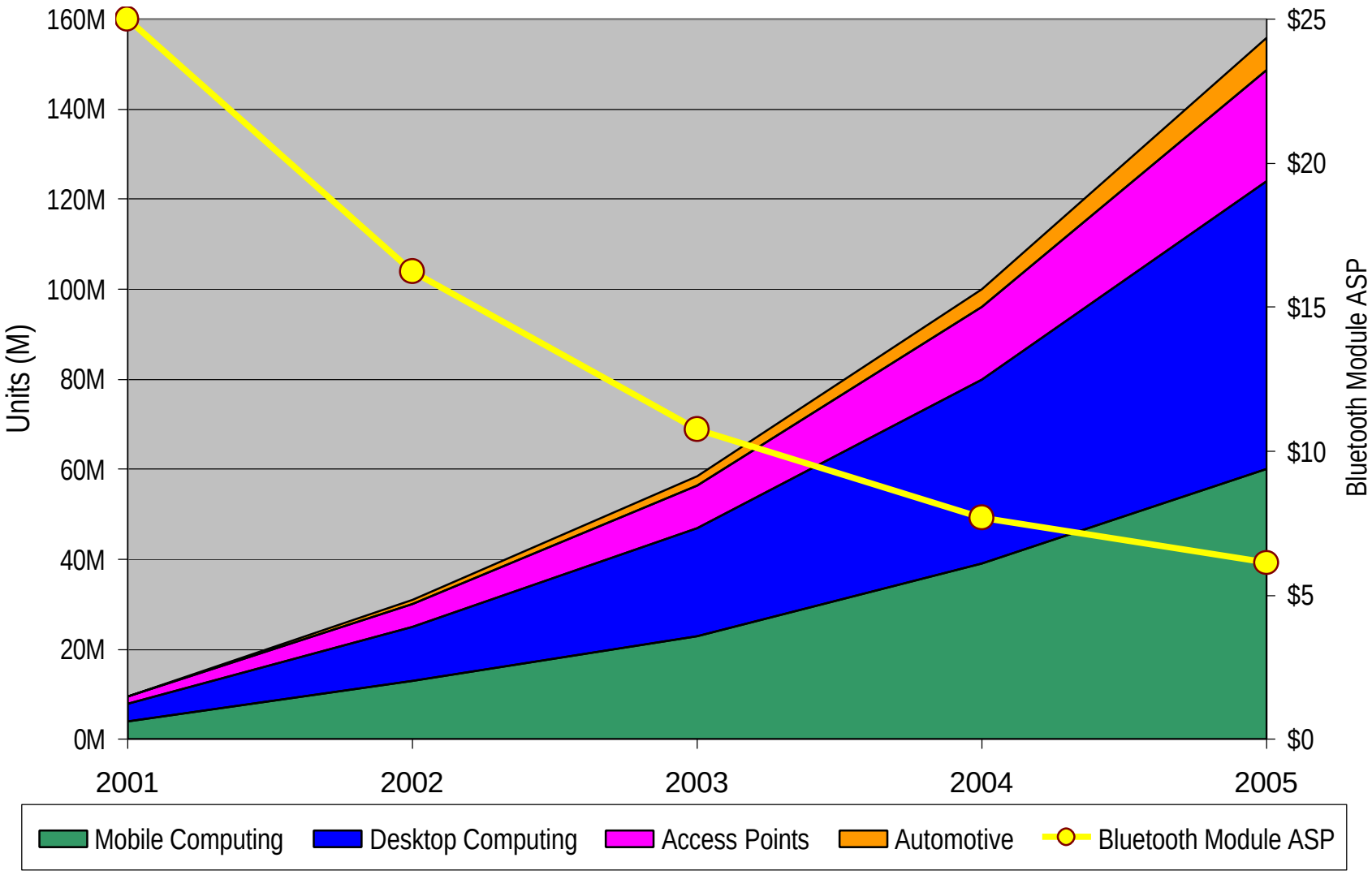
- File transfer
  - MP3
  - Digital pictures
- Peripheral connectivity
  - Keyboard/mouse/remote
  - Printer

Bluetooth Market Forecast



Source: Intex Management Services Limited, April 2000

Bluetooth Market Forecast

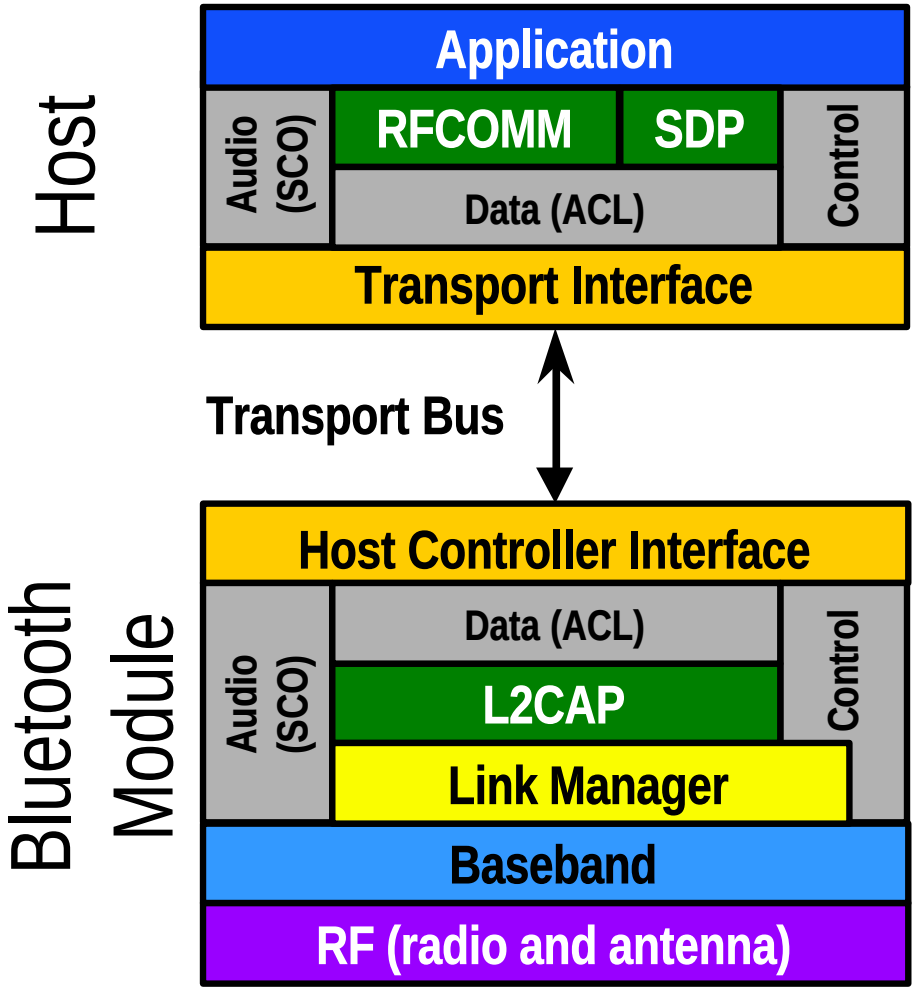


Source: Intex Management Services Limited, April 2000

Bluetooth Vs. Other WLANs

	Technology					
	Bluetooth	HomeRF	802.11b	HyperLAN	802.11a	HypyerLAN2
Frequency Band	2.4GHz	2.4GHz	2.4GHz	2.4GHz	5GHz	5GHz
Technology	Frequency Hopping Spread Spectrum	Frequency Hopping Spread Spectrum	Direct Sequence Spread Spectrum	Guassian Minimum Shift Keying	Orthogonal Freq. Division Multiplexing	Orthogonal Freq. Division Multiplexing
Performance	720Kbps	1.6Mbps	11Mbps	23Mbps	~50Mbps	~50Mbps
Range	<10 meters	50 meters	100 meters	?	?	?
Power	Very Low	Medium	Medium	Medium	Medium High?	Medium High?
Relative Cost	Low/ Very Low	Medium/Low	Medium	Medium	High	High
Target Applications	Cable Replacement Wireless Data Wireless Voice Personal Networks	Wireless Data Wireless Voice	Wireless Data	Wireless Data	Wireless Data	Wireless Data
Fixed N/W Support	PPP, Ethernet	?	Ethernet	Ethernet	Ethernet	Ethernet, IP, ATM, PPP, 1394, UMTS
Key Features	Very Low Power Voice and Data Roaming Low Cost Good noise immunity	Voice and Data Moderate Cost	Good Performance	Good Performance	High Performance	High Performance
Promoters	2000+	<50	~100	<50	~100	<50
Regional Support	Worldwide	US	US/Asia	Europe	US	Europe
Shipping	Now	Now	Now	Now	2001	2001

Inside Bluetooth



Host Application

API and Legacy Support Modules

Bluetooth HCI Driver

Physical I/F

Physical I/F

HCI Firmware

Logical Link Control & Data Adaptation

Physical Link Control

Data Processing & Transmission Mgmt.

Transmission/Reception

L2CAP

Logical Link Control and Adaptation Protocol

- Manages the creation and termination of virtual connections with other Bluetooth devices
  - Negotiates and/or dictates parameters
    - Including Security and Quality of Service (QoS)
- Manages ACL data flow between the host and Link Manager
  - Multiplixing of multiple concurrent host I/O operations
  - Segmentation And Reassembly (SAR) of various data formats for baseband compatibility

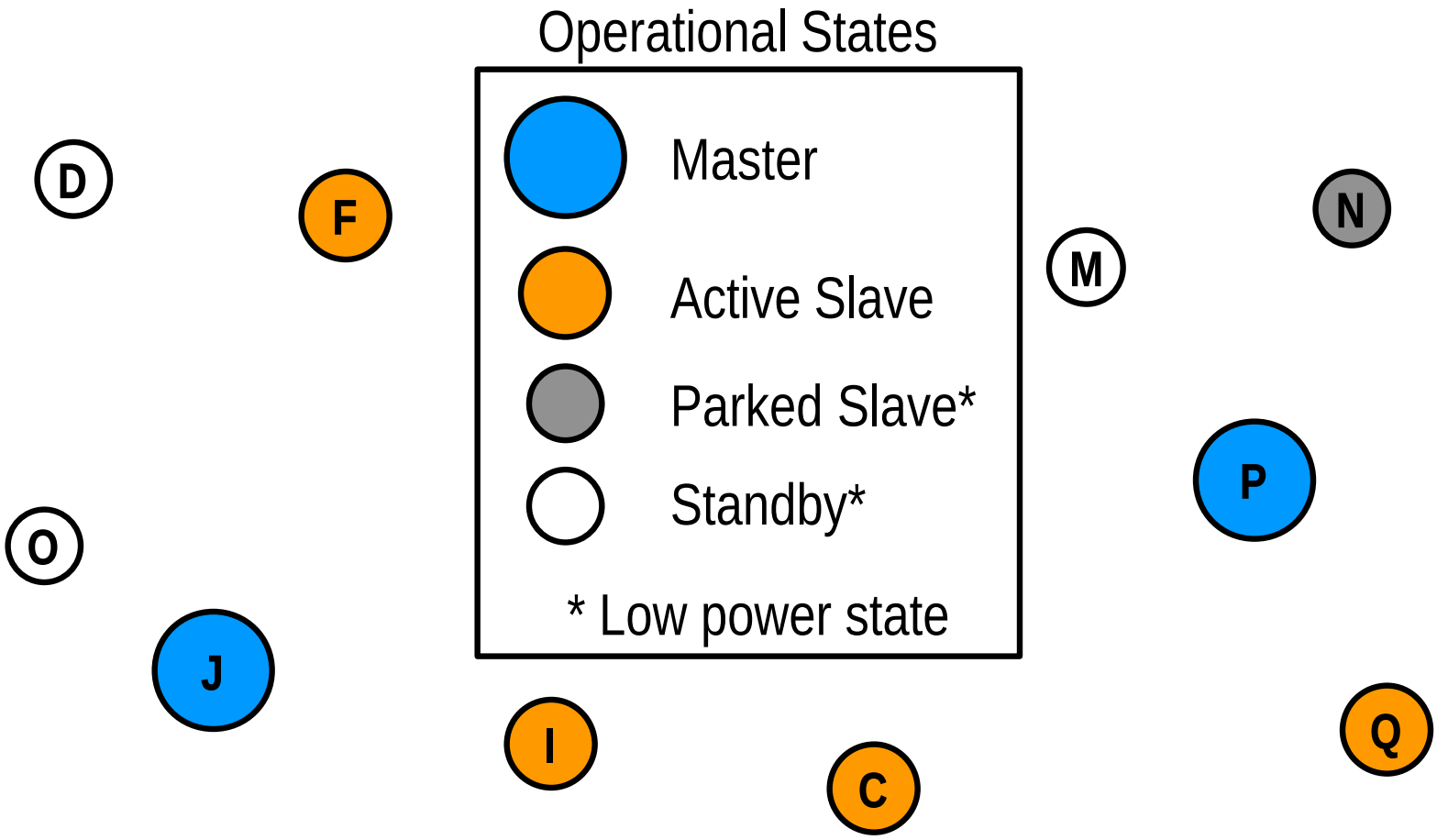
Link Manager

- Physically manages creation, configuration, and termination of device to device links
- Also manages ACL data flow between the L2CAP and Baseband through established links
  - Forwards data from the L2CAP to the Baseband with its associated link specific transmission parameters
  - Forwards data from the Baseband back to the L2CAP associated to its specific source link

Baseband

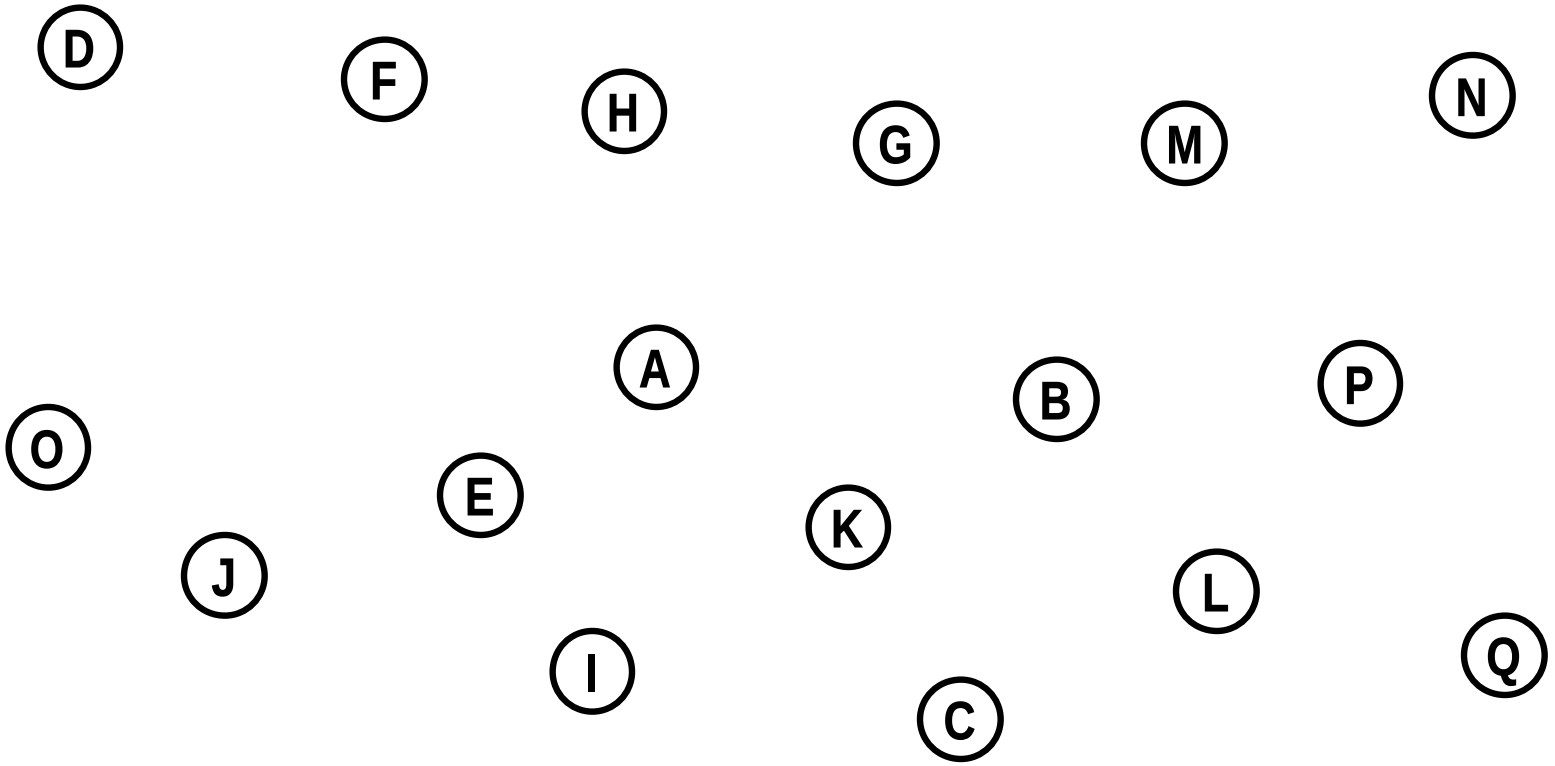
- Performs all digital data processing operations
  - Speech coding
  - Data whitening
  - Optional encryption/decryption
  - Packetization
  - Header and payload error detection and correction
- Calculates and controls transmission frequency
  - Supporting Bluetooth's 80 channel Frequency Hopping (FH) spread spectrum transmission method

How Does Bluetooth Work?



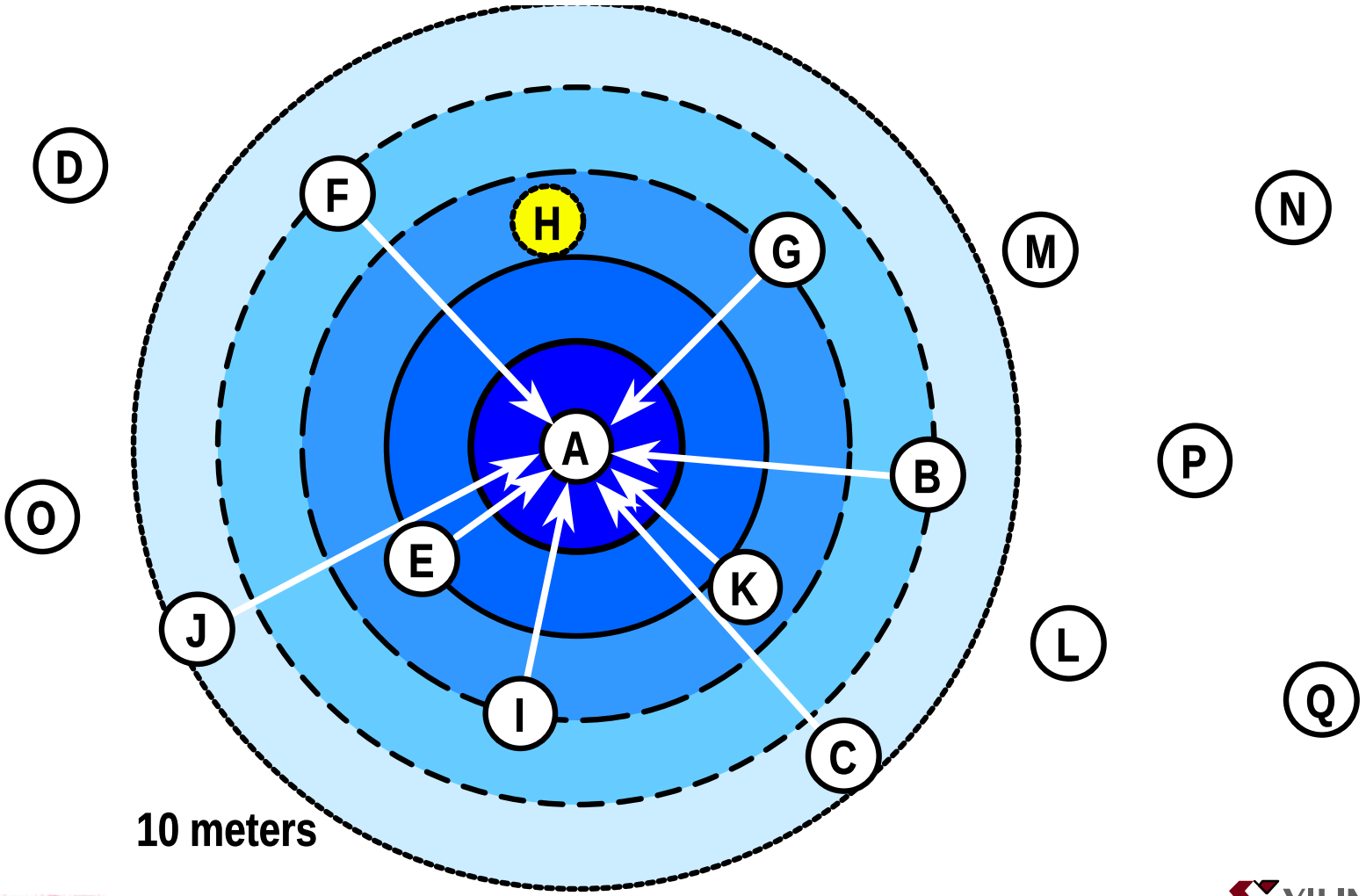
In the Beginning

- Initially Bluetooth devices only know about themselves
  - Everyone passively monitors in Standby mode
  - No devices are synchronized



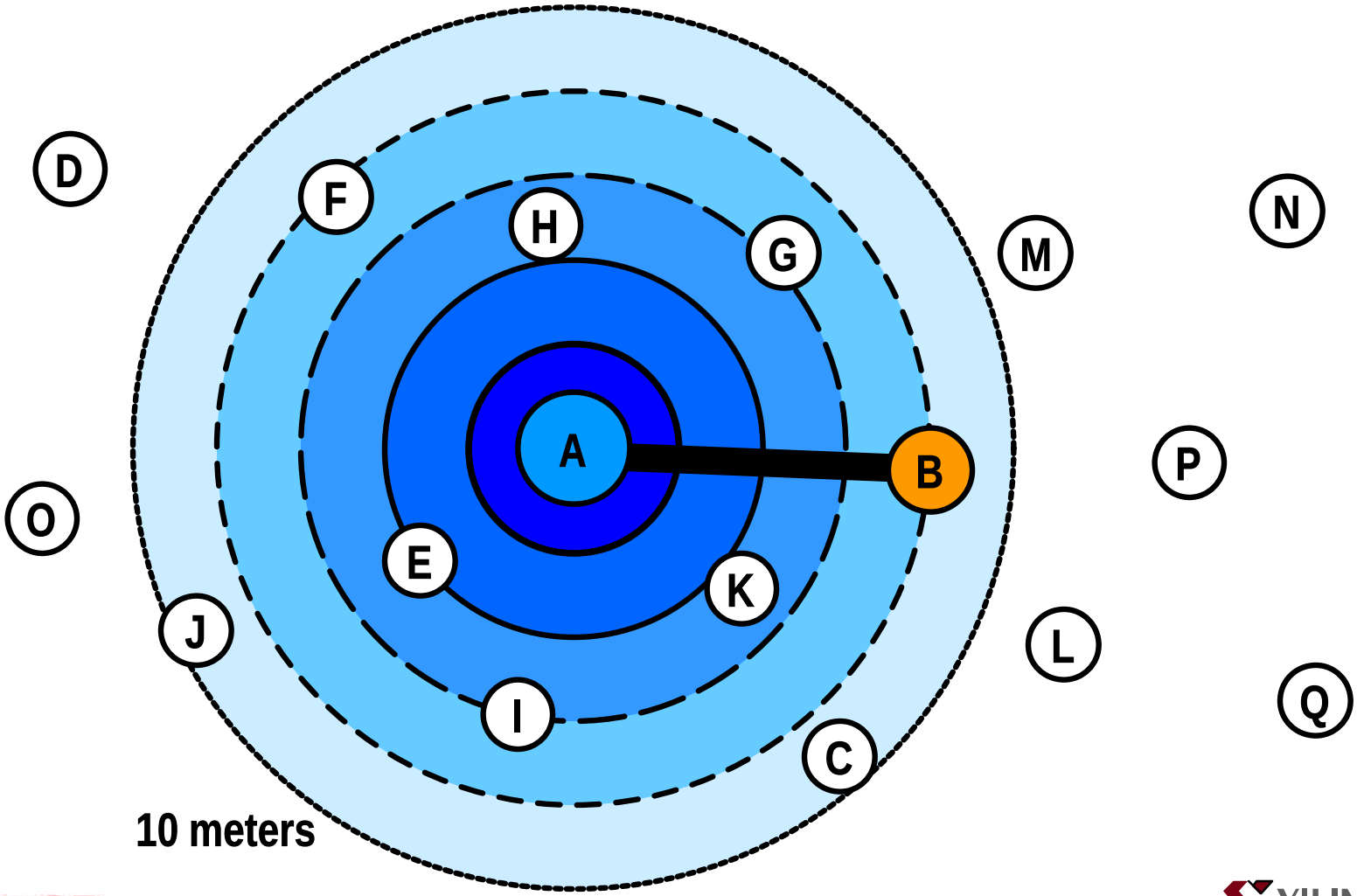
Inquiry
Discovering Who's Out There

- Inquiry discovers what other devices within range



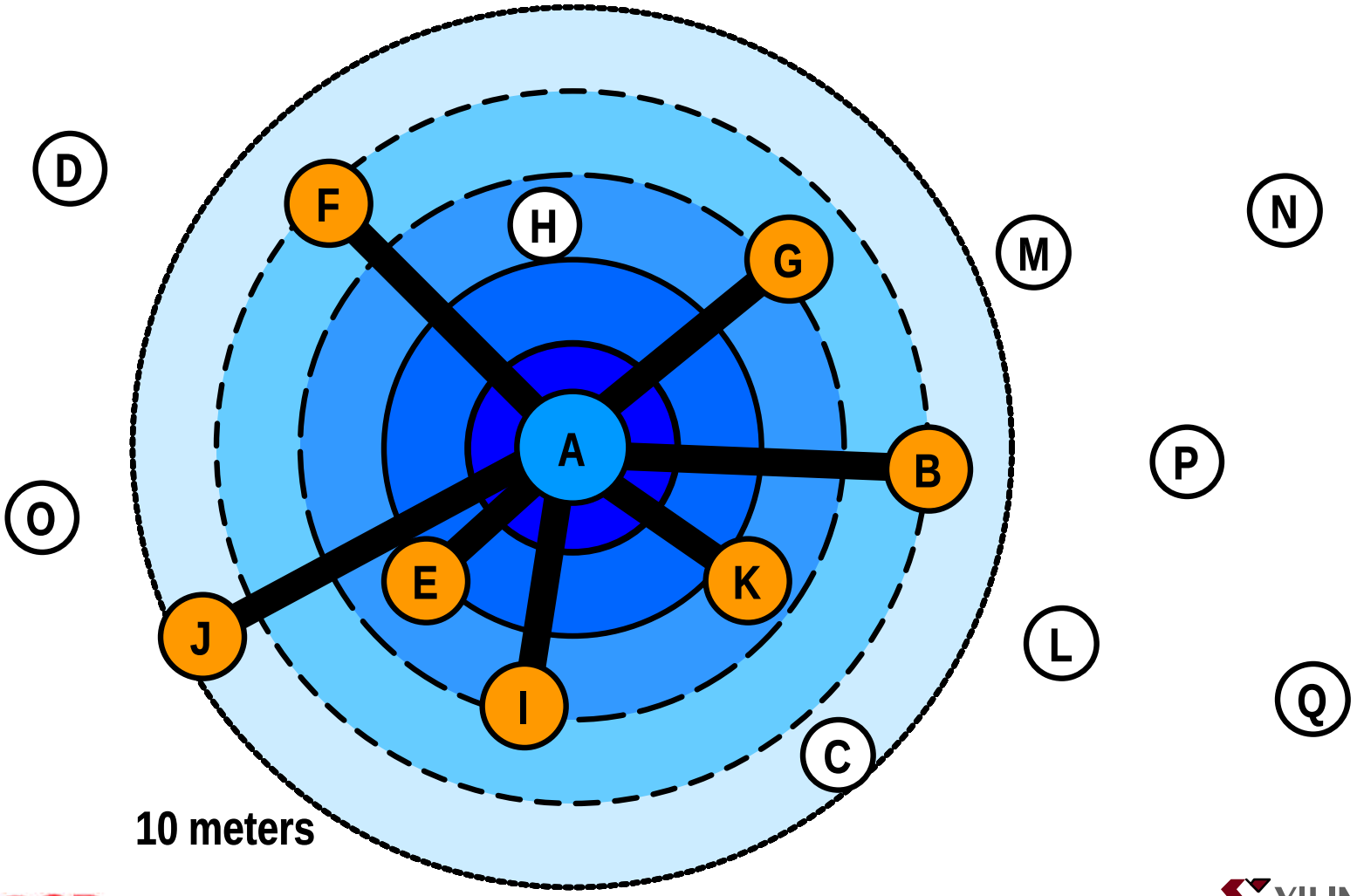
Paging
Creating a Piconet

- Paging creates a Master/Slave link called a Piconet



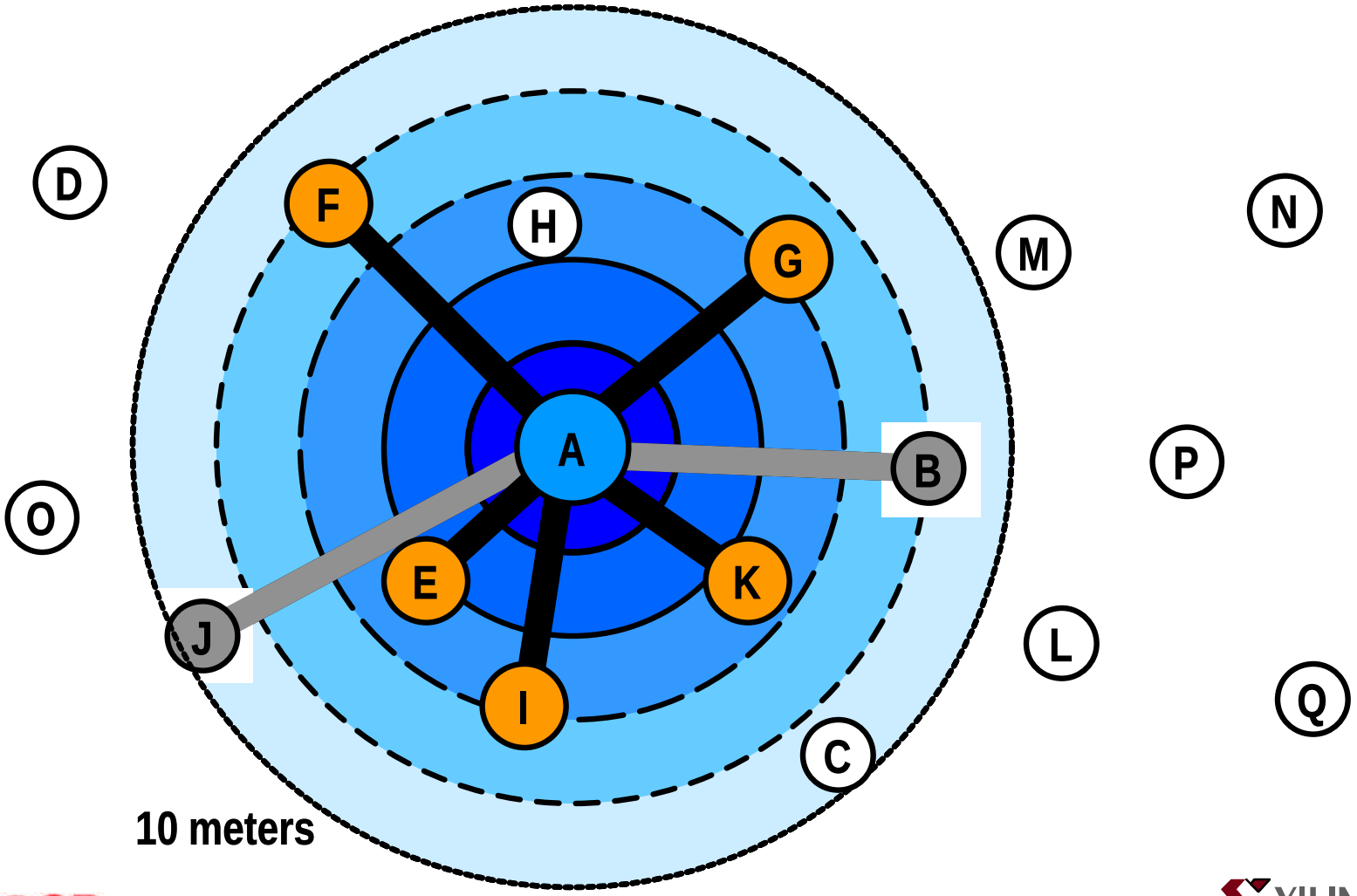
Expanding a Piconet (1)

- Successive Pages can attach up to 7 Active Slaves to a Piconet at one time



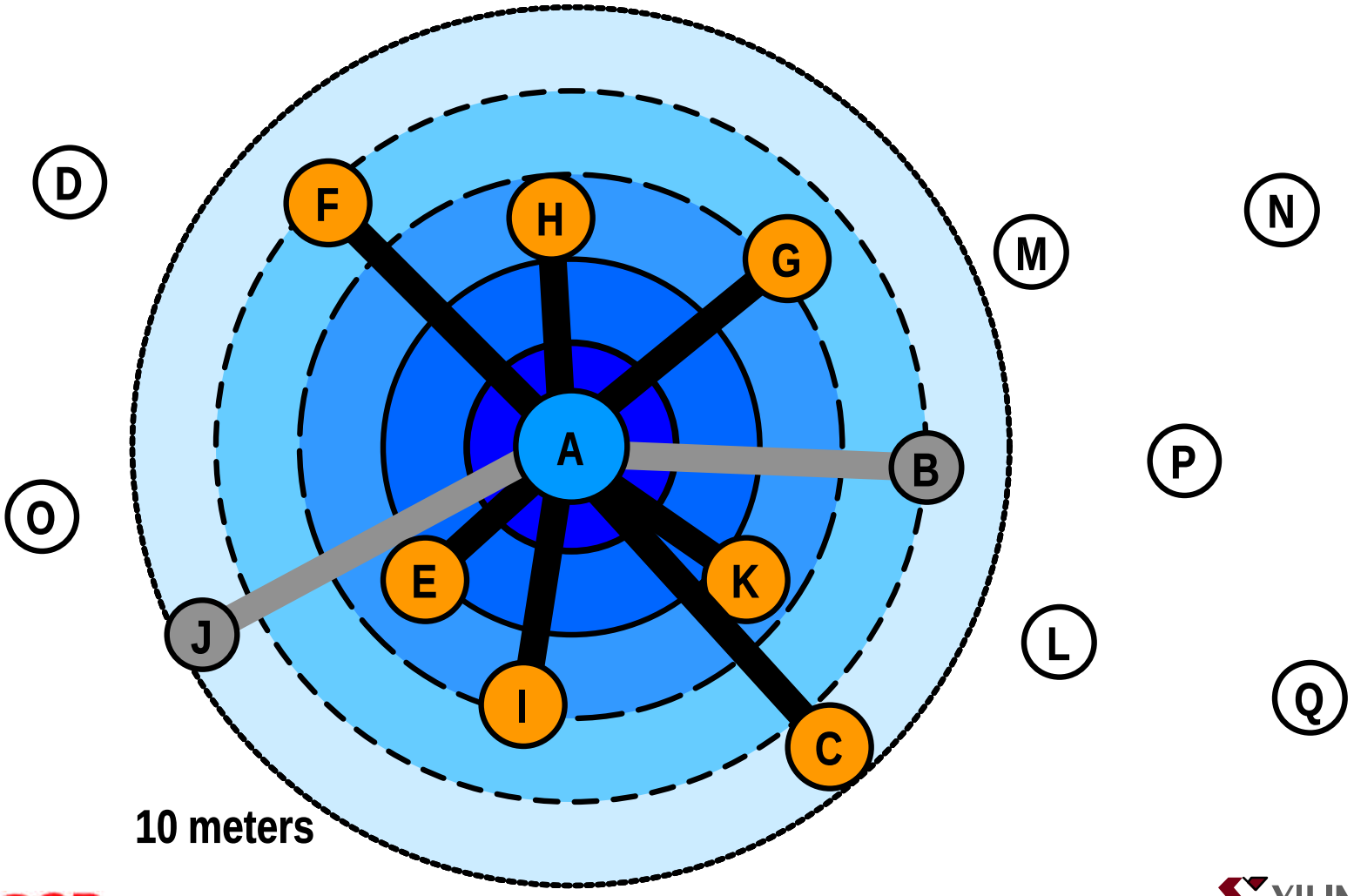
Parking

- To save power and/or to connect to even more devices Active Slaves can be Parked *(up to 256 total!)*



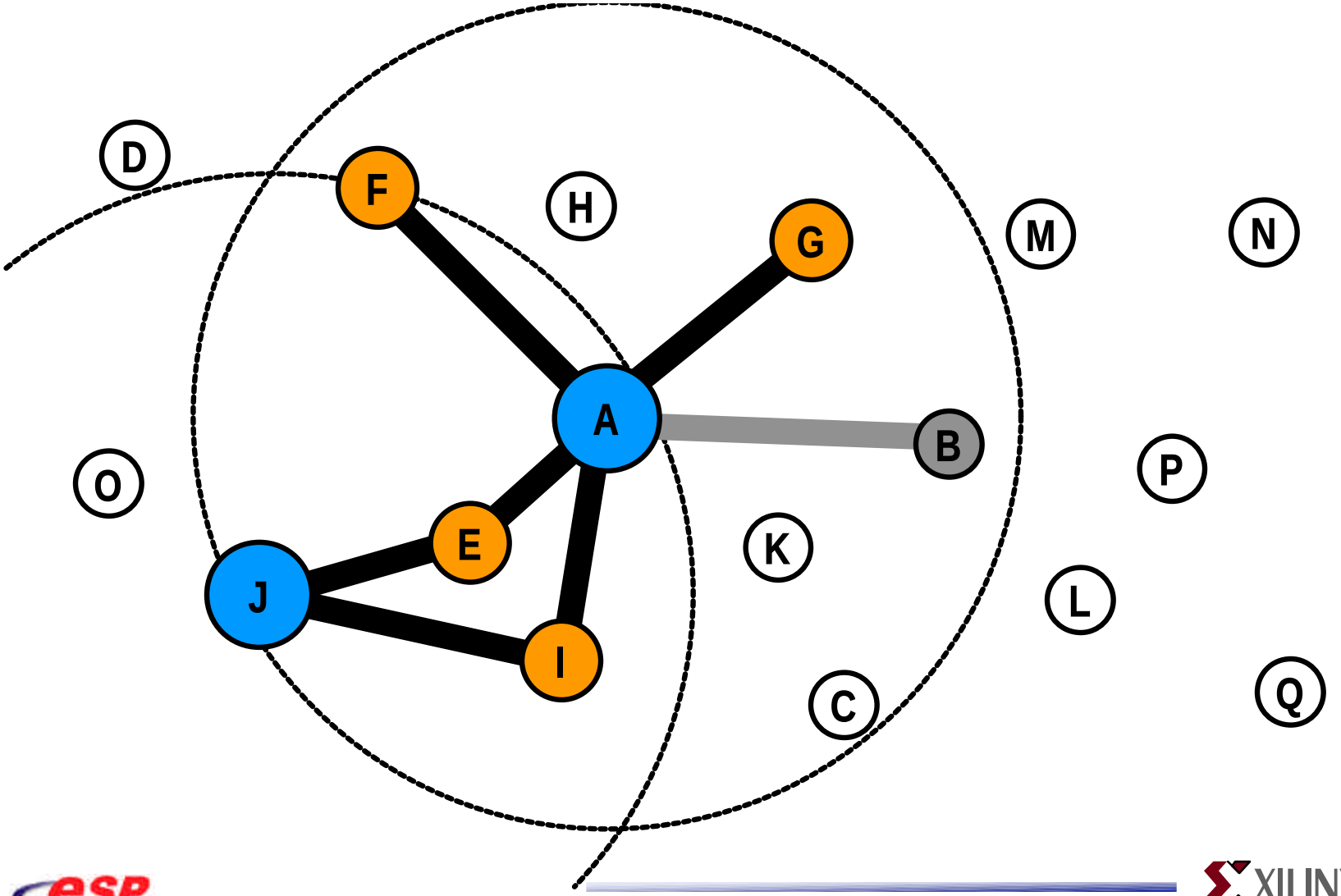
Expanding a Piconet (2)

- Masters can then attach additional Active Slaves using Active Member Addresses freed up through Parking



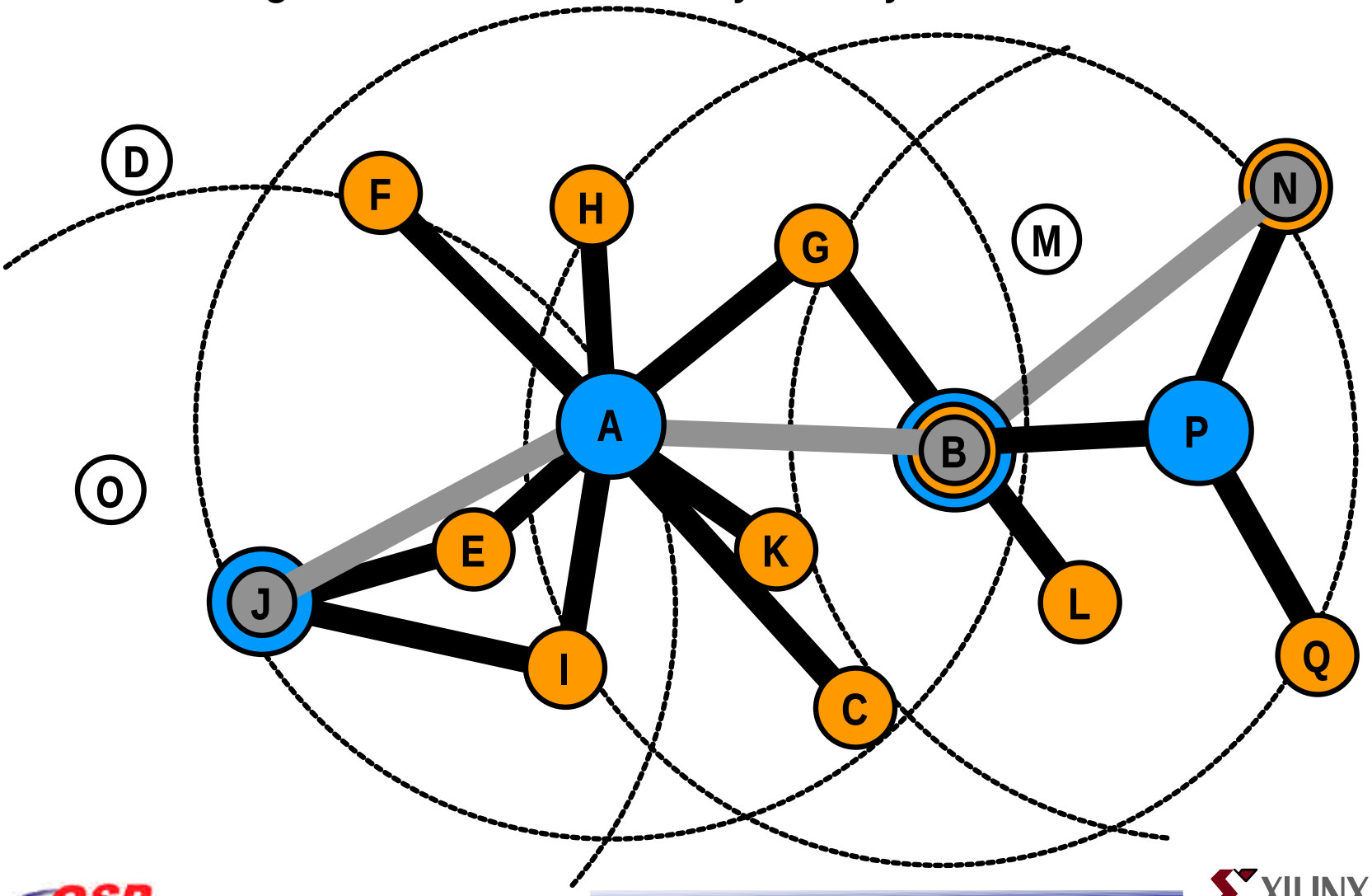
Scatternets

- Bluetooth devices can participate in multiple Piconets simultaneously creating a topologies called Scatternets



Advanced Scatternets

- Scatternets can evolve into extremely complex structures creating a rich fabric of many, many, devices



Bluetooth Radio Basics

- Normal range: 10 meters
- Normal xmit power: 1 milliWatt
- Receiver sensitivity: -70 dB
- Frequency band: 2.4 GHz(ISM)
- Max data rate: 721Kbps + 56Kbps X 3 (voice)

Bluetooth Radio Frequency Band

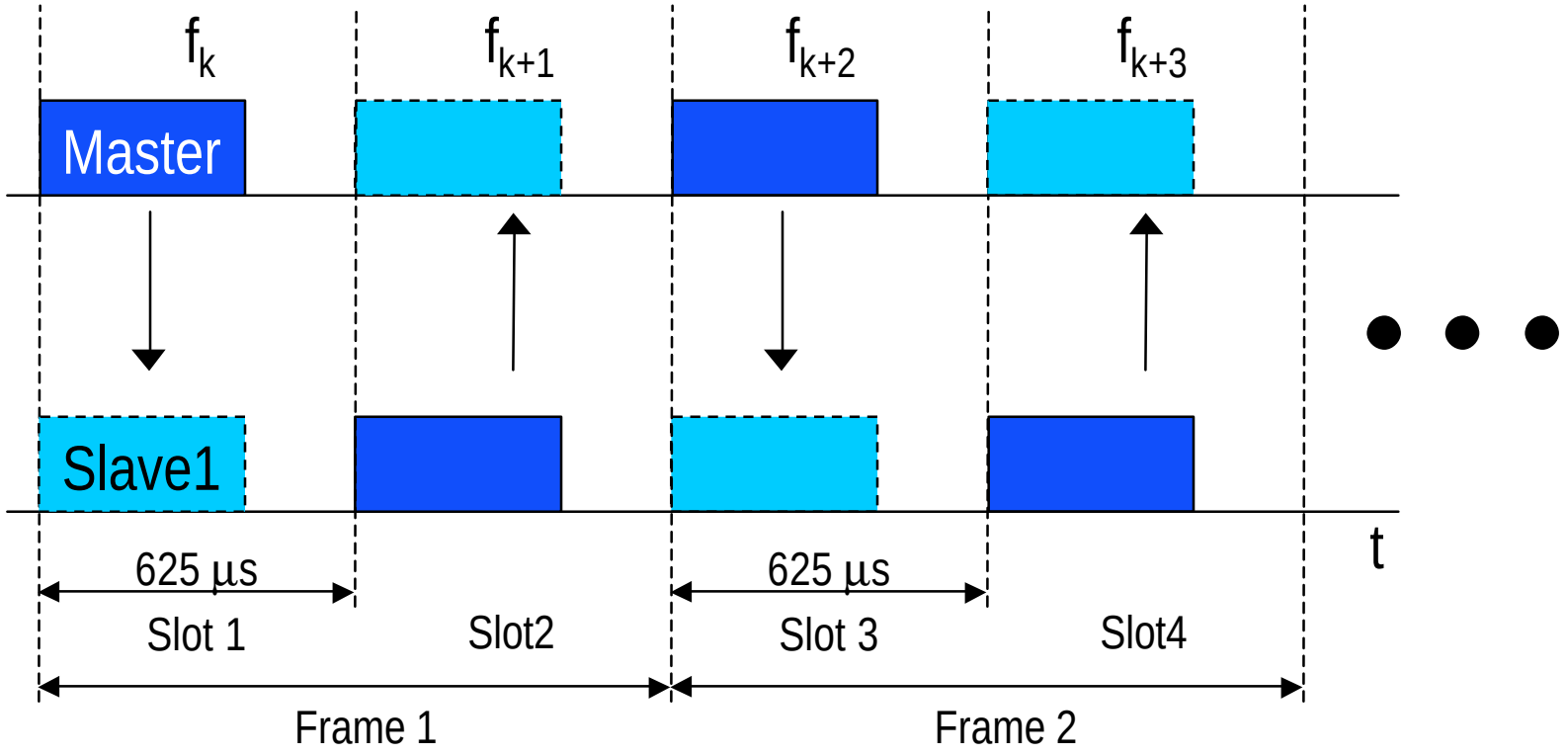
- ISM (Industrial, Scientific, Medical) band
  - 2.402GHz - 2.480GHz (79MHz total bandwidth)
- Advantages
  - Free
  - Open to everyone worldwide
- Disadvantages
  - Noise sources from everywhere
    - Cordless phones, microwave ovens, garage door openers, other wireless LAN technologies, baby monitors,...

Bluetooth's Noise Solutions

- Frequency Hopping (FH) Spread Spectrum technology
  - Divides the band into 79 separate 1MHz channels
- Uses short packets and makes 1600 hops/second
  - Minimizes exposure to noisy channels
  - Enables bad voice packets to be discarded
- Forward Error Correction (FEC) of data packets
  - Data often recoverable even on a noisy channel without retransmission

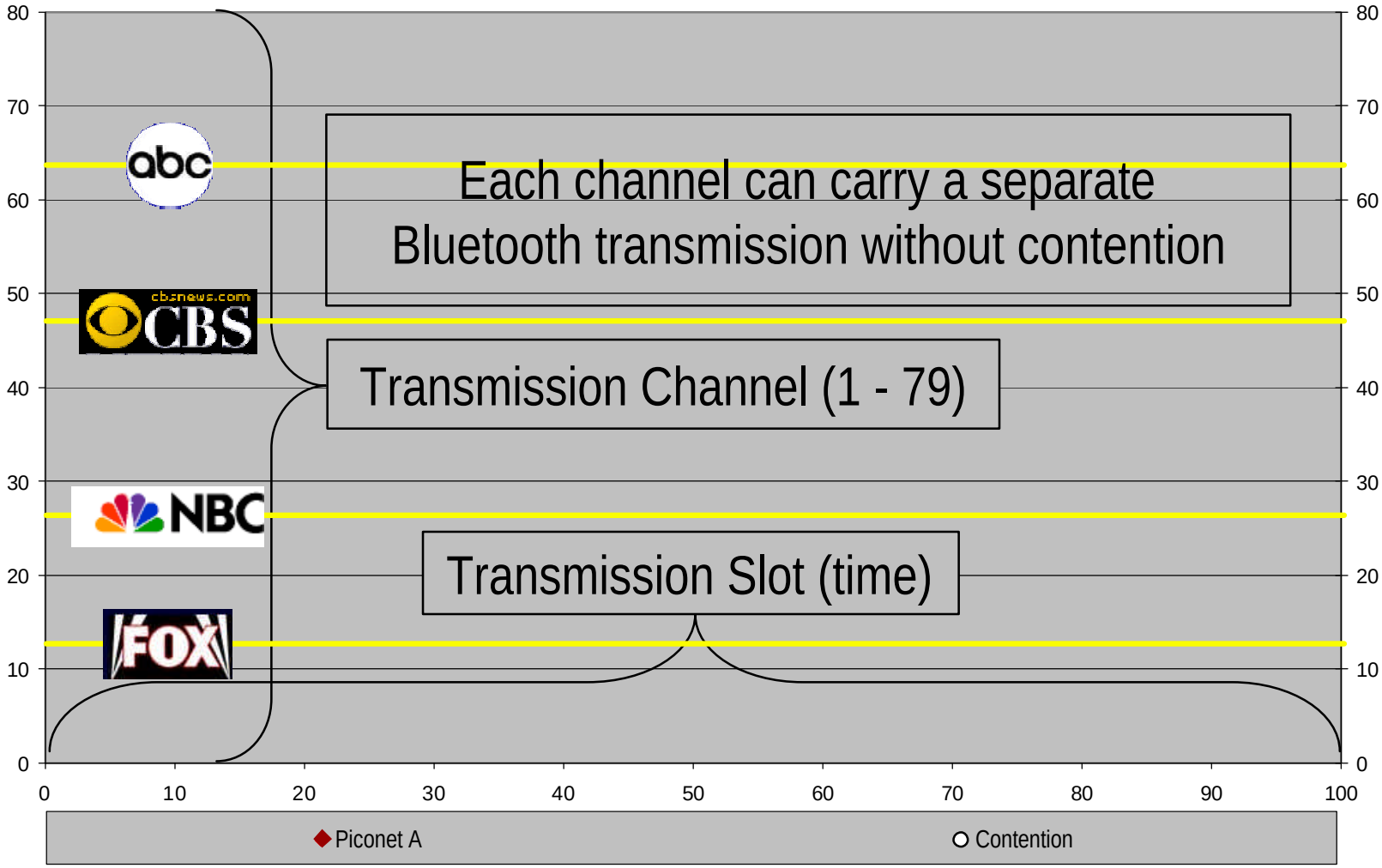
Bluetooth Transmission Protocol

Frequency Hopping & Time Division Duplexing

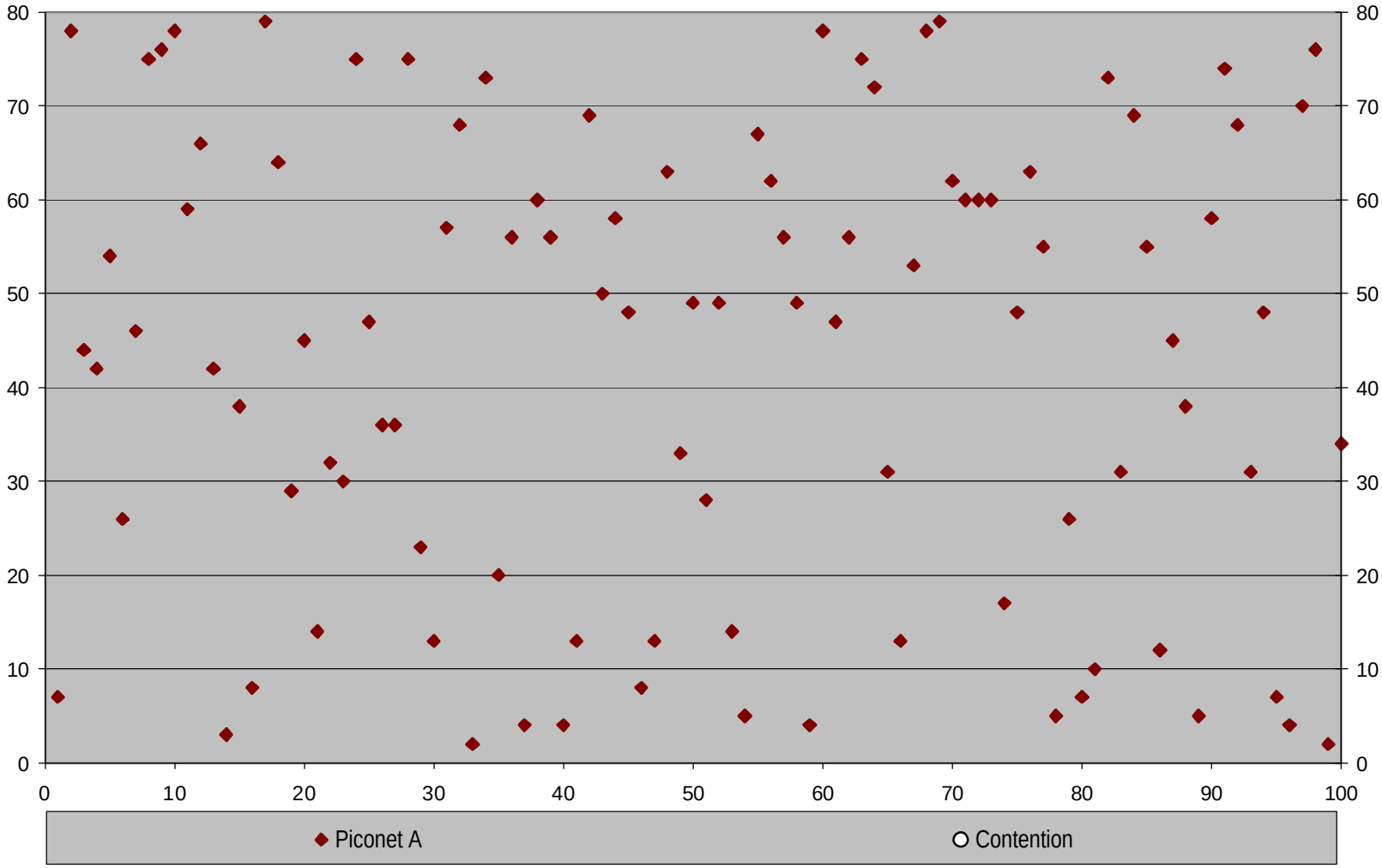


- Complete packet transmission occurs during a Slot
- Frequency hops from Slot to Slot to Slot
- Frames define matched Master / Slave Slot transmissions

Frequency Hopping
Graphically Illustrated

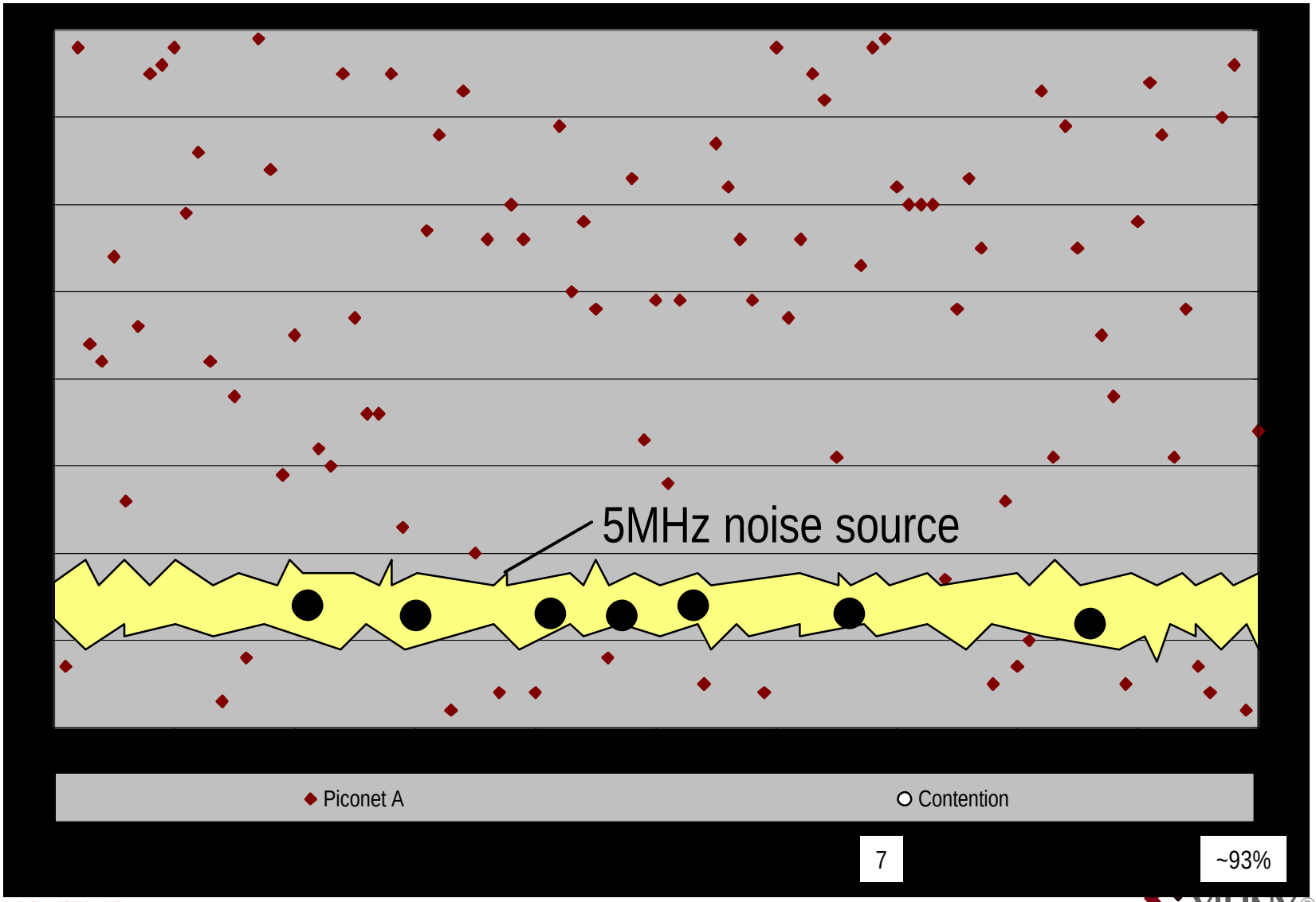


Each Bluetooth Piconet Randomly Changes Frequency Slot by Slot

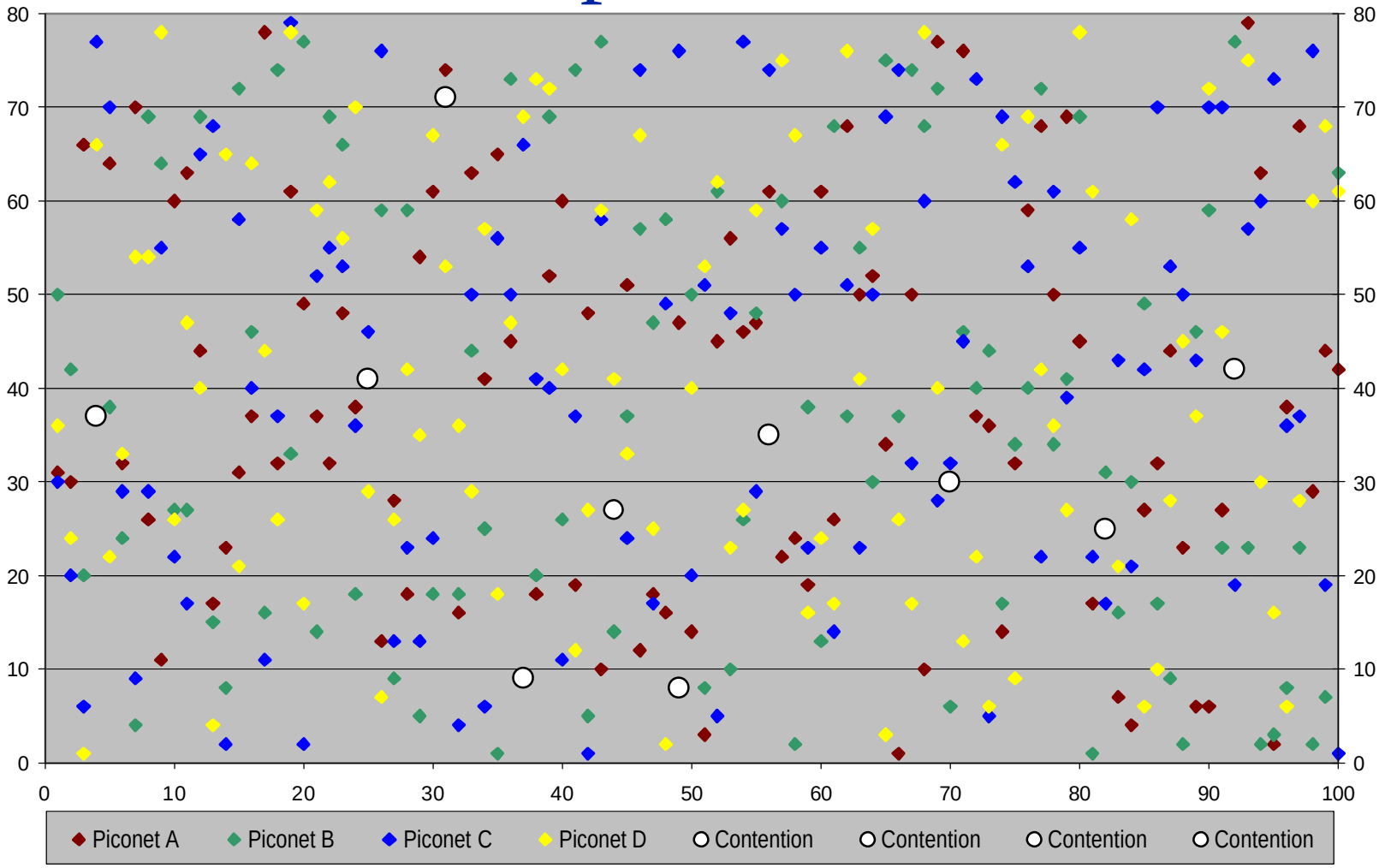


Active Piconets: 1 Total Transmission Slots: 100 Transmission Slots Hit: 0 Transmission Efficiency: ~100%

Frequency Hopping Minimizes Exposure to Data Loss Due to Noise

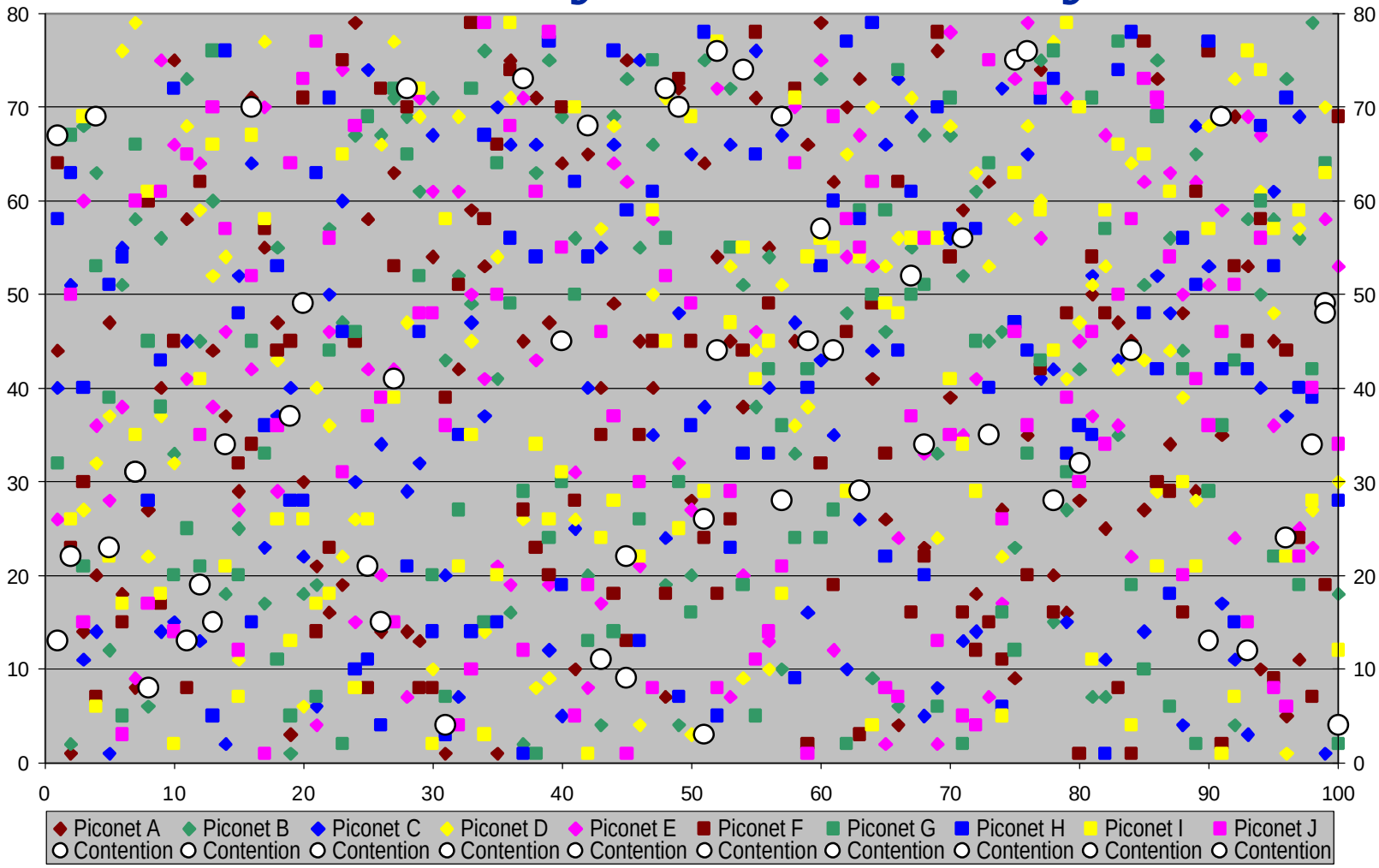


Frequency Hopping With Multiple Piconets



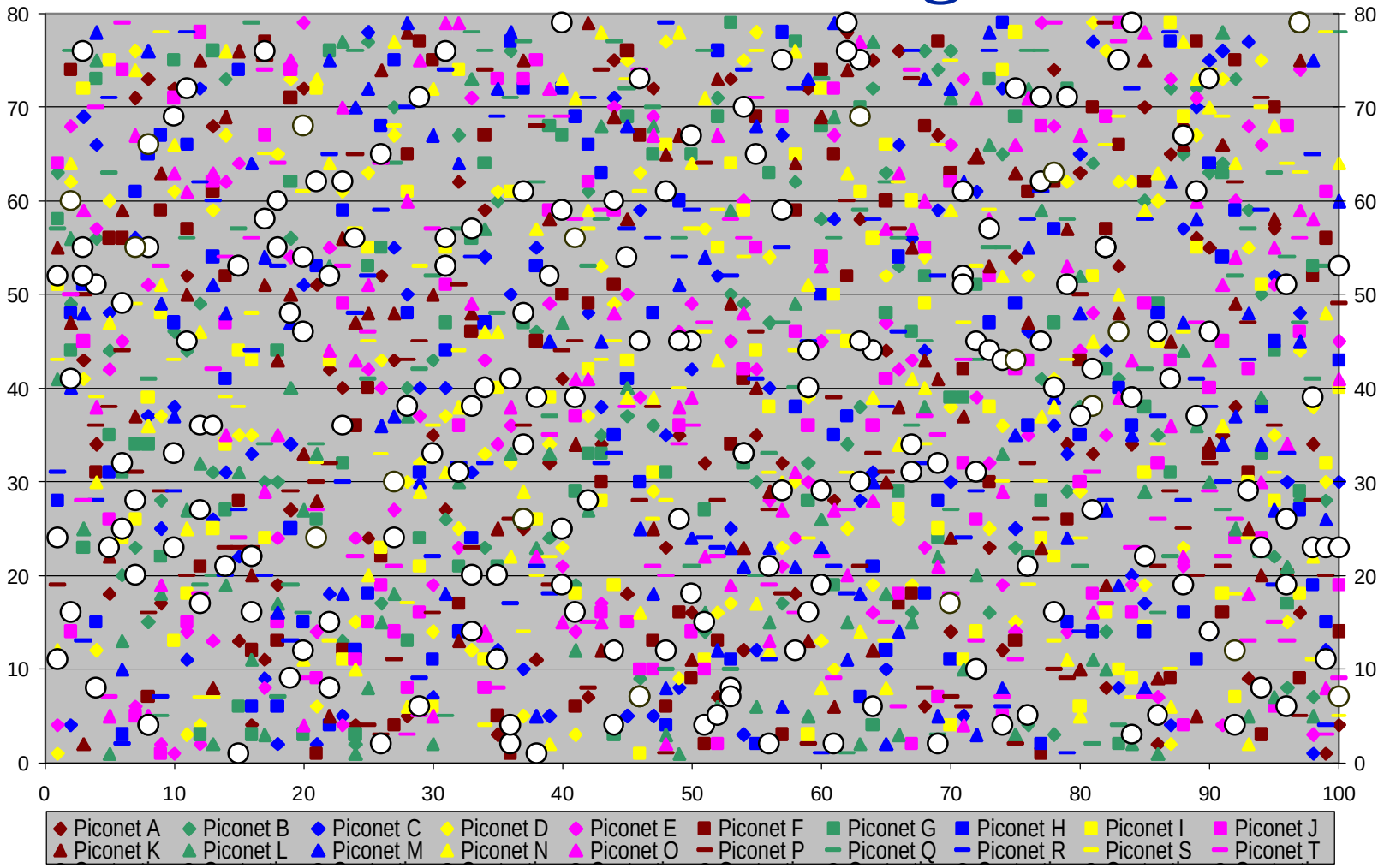
Active Piconets: 4 Total Transmission Slots: 400 Transmission Slots Hit: 20 Transmission Efficiency: ~95%

Bluetooth Piconets Degrade Gracefully with Density...



Active Piconets: 10 Total Transmission Slots: 1000 Transmission Slots Hit: 112 Transmission Efficiency: ~89%

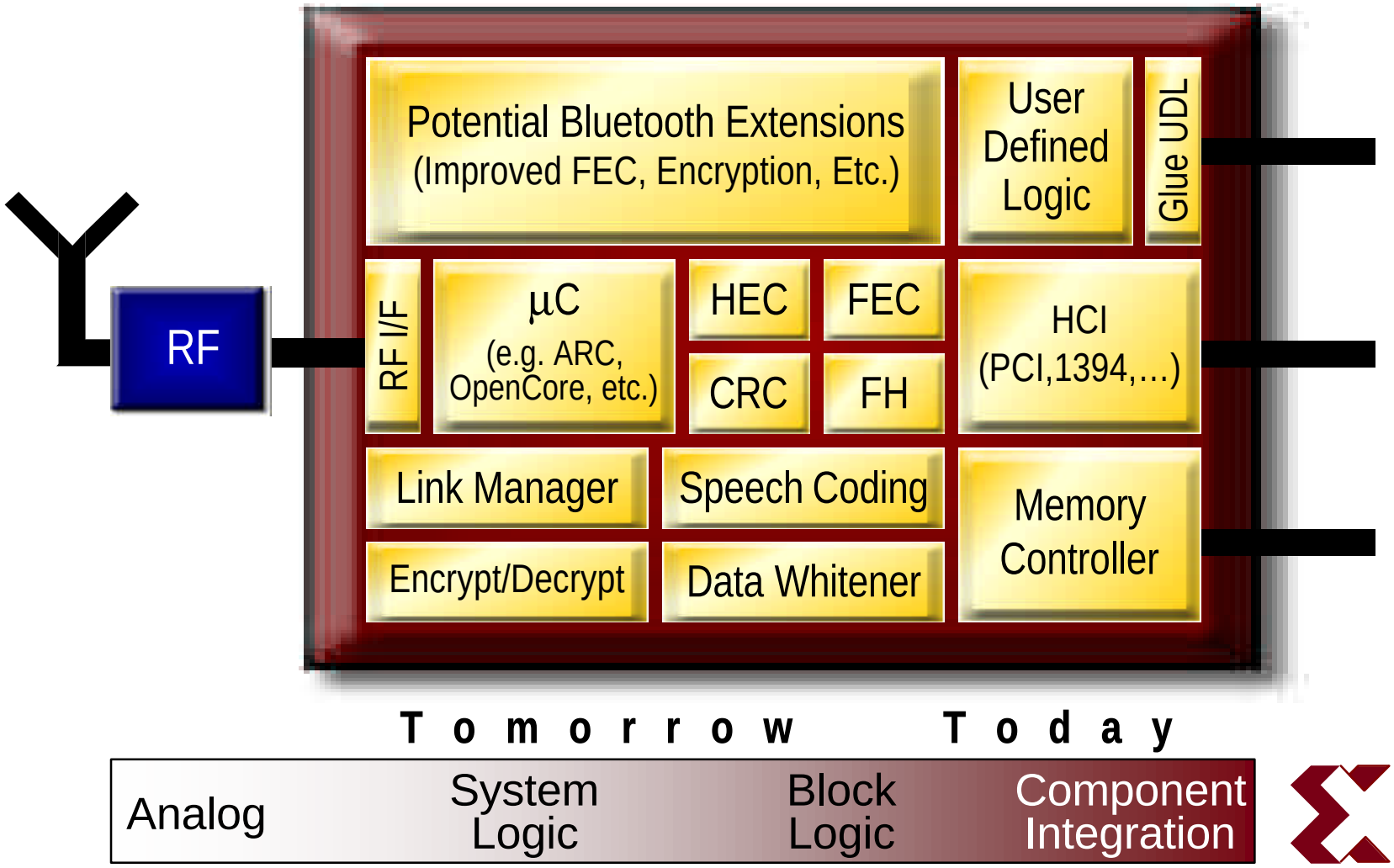
...And Maintain Reasonable Performance Even In High Densities



Active Piconets: 20 Total Transmission Slots: 2000 Transmission Slots Hit: 420 Transmission Efficiency: ~79%

Xilinx in Bluetooth

Opportunities for Spartan II and CoolRunner

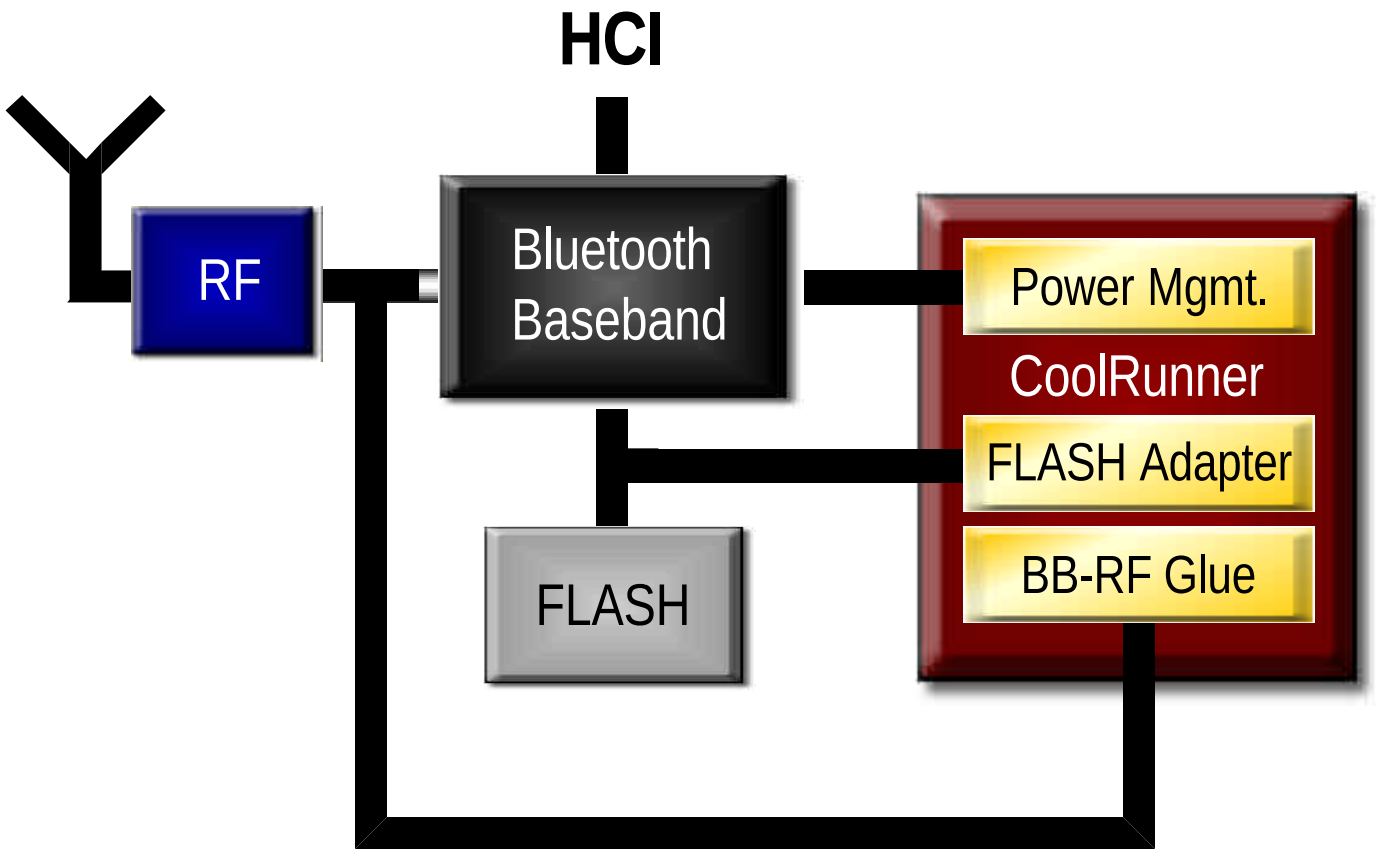


Xilinx in Bluetooth

- Today
  - Component integration
  - Power Management
  - HCI bridging
  - System integration
- Tomorrow
  - Custom configurations and Bluetooth extensions
    - Multi-RF access points
    - Enhanced Bluetooth solutions
    - Derivative “Bluetooth-based” solutions

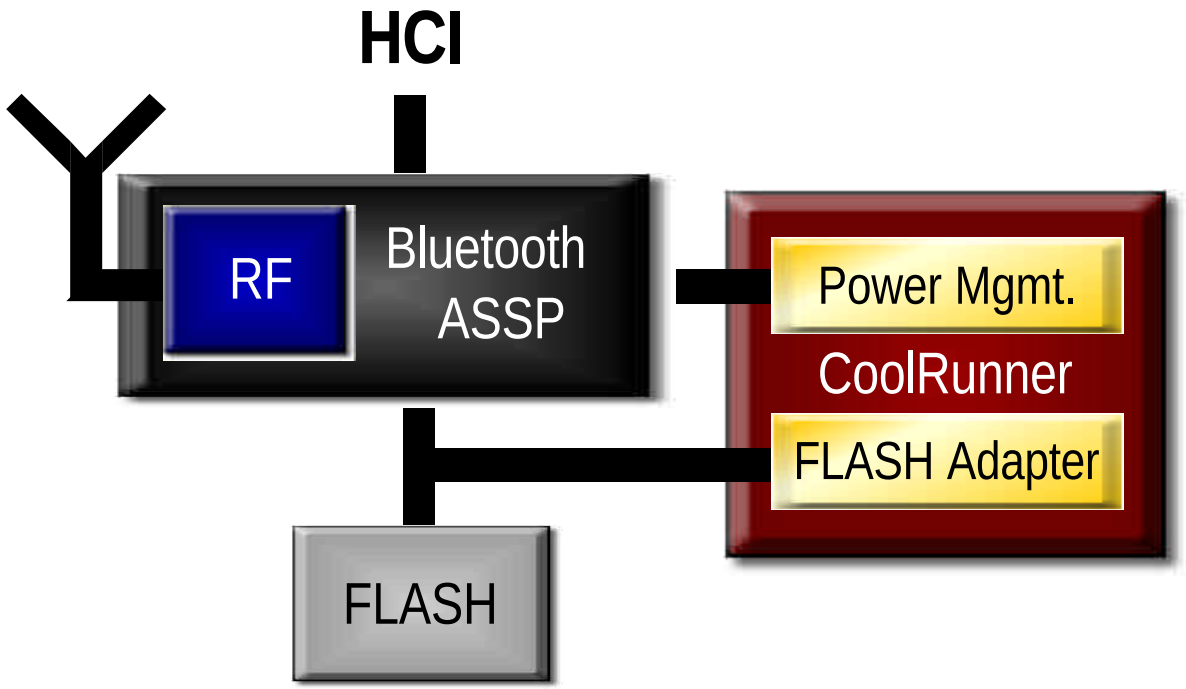
Xilinx in Bluetooth Today (1)

CoolRunner Component Integration and Power Management



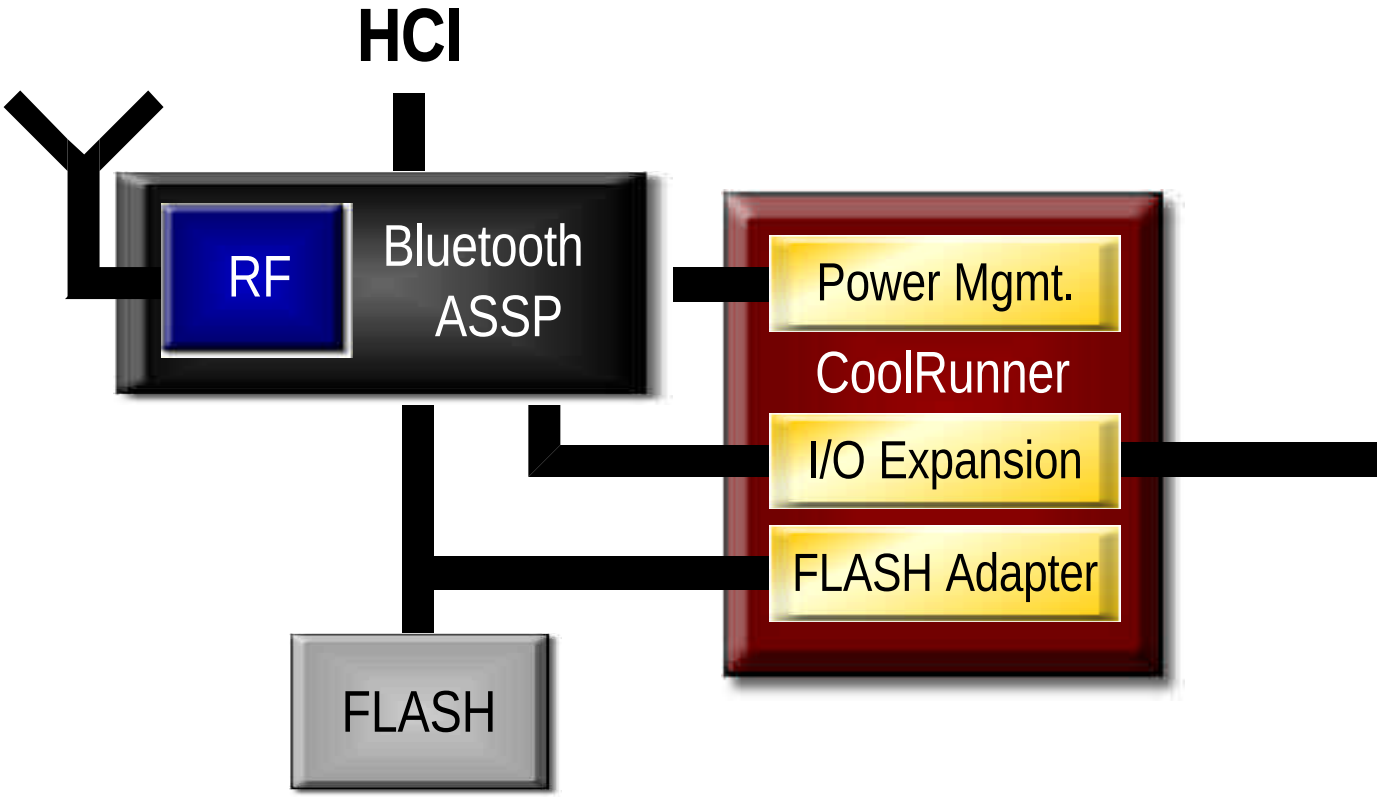
Xilinx in Bluetooth Today (2)

CoolRunner Component Integration and Power Management



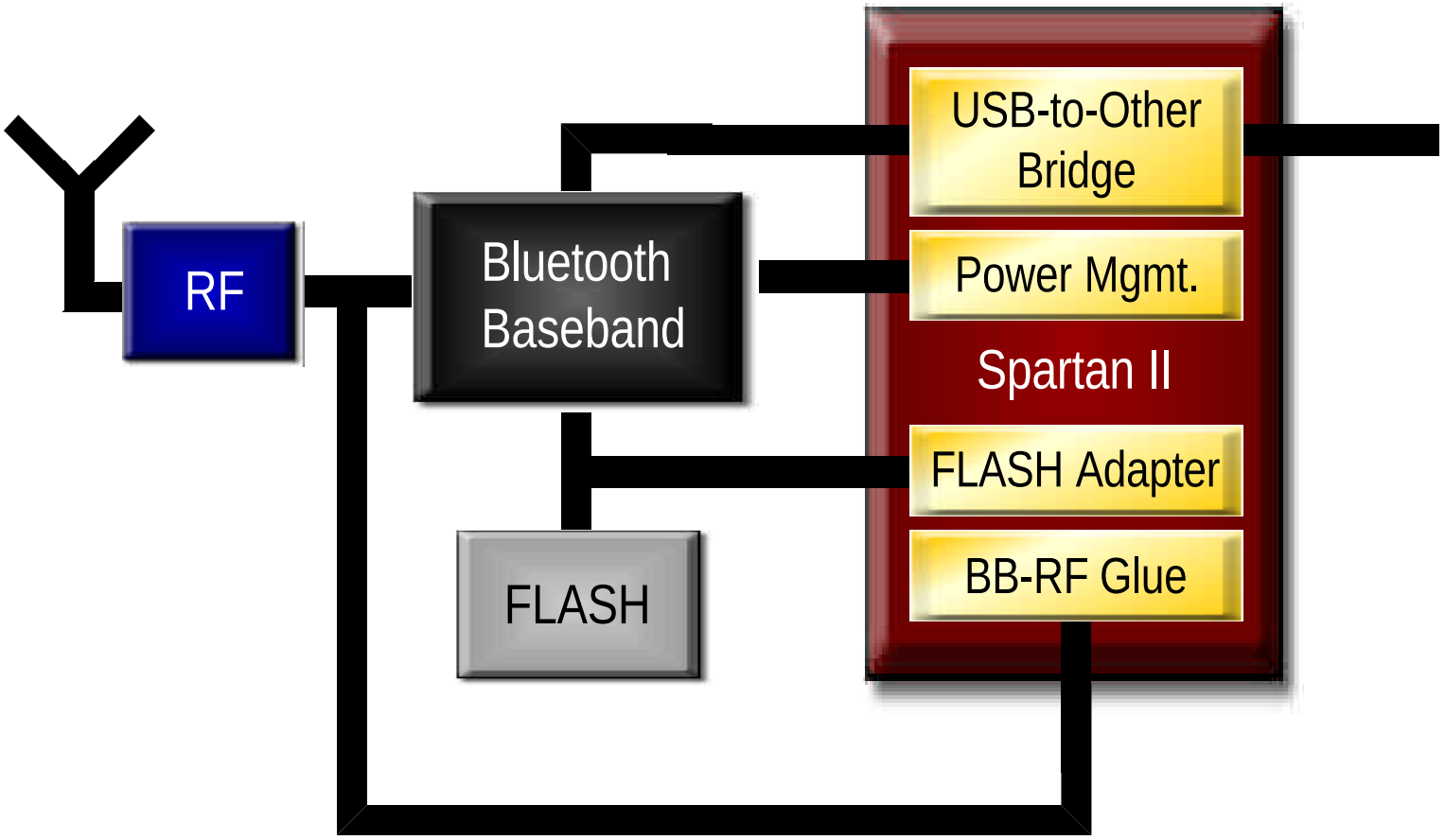
Xilinx in Bluetooth Today (3)

CoolRunner Component Integration, Power Management, and System Expansion



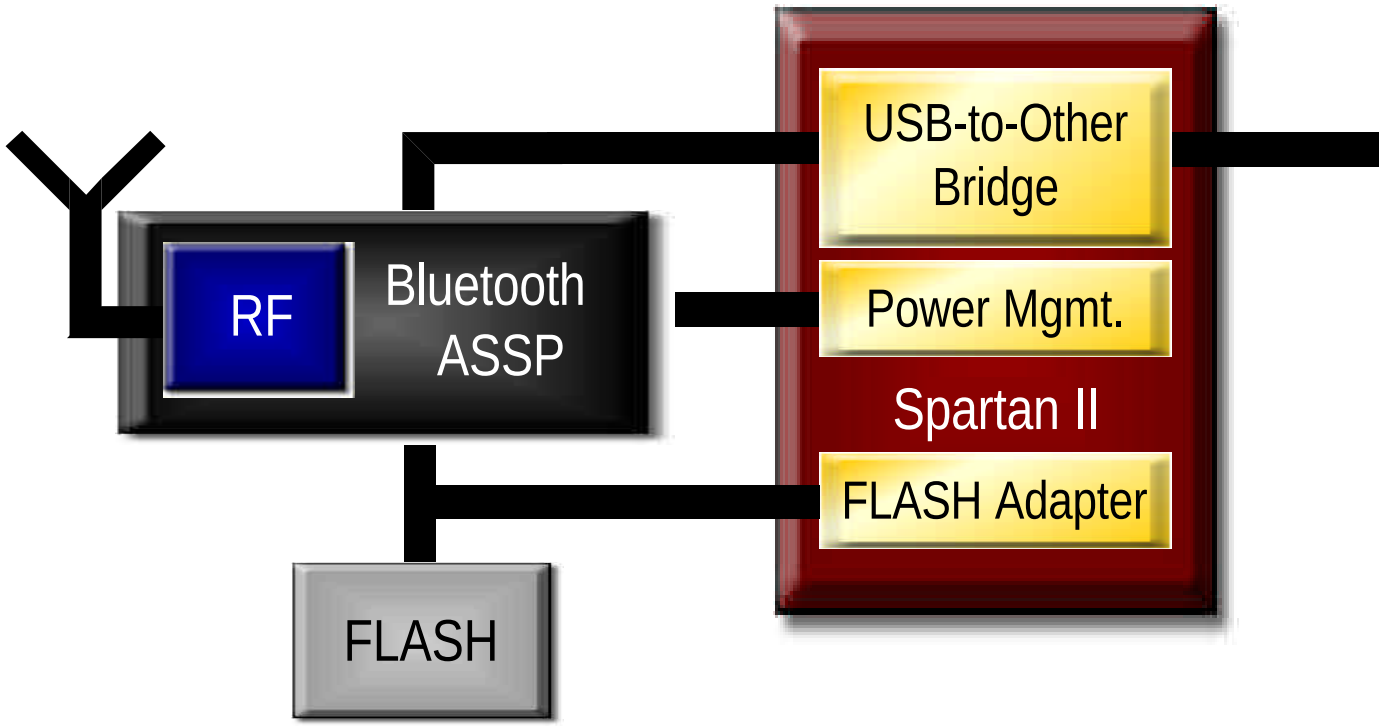
Xilinx in Bluetooth Today (4)

Spartan II Component Integration, Power Management, and HCI Bridging



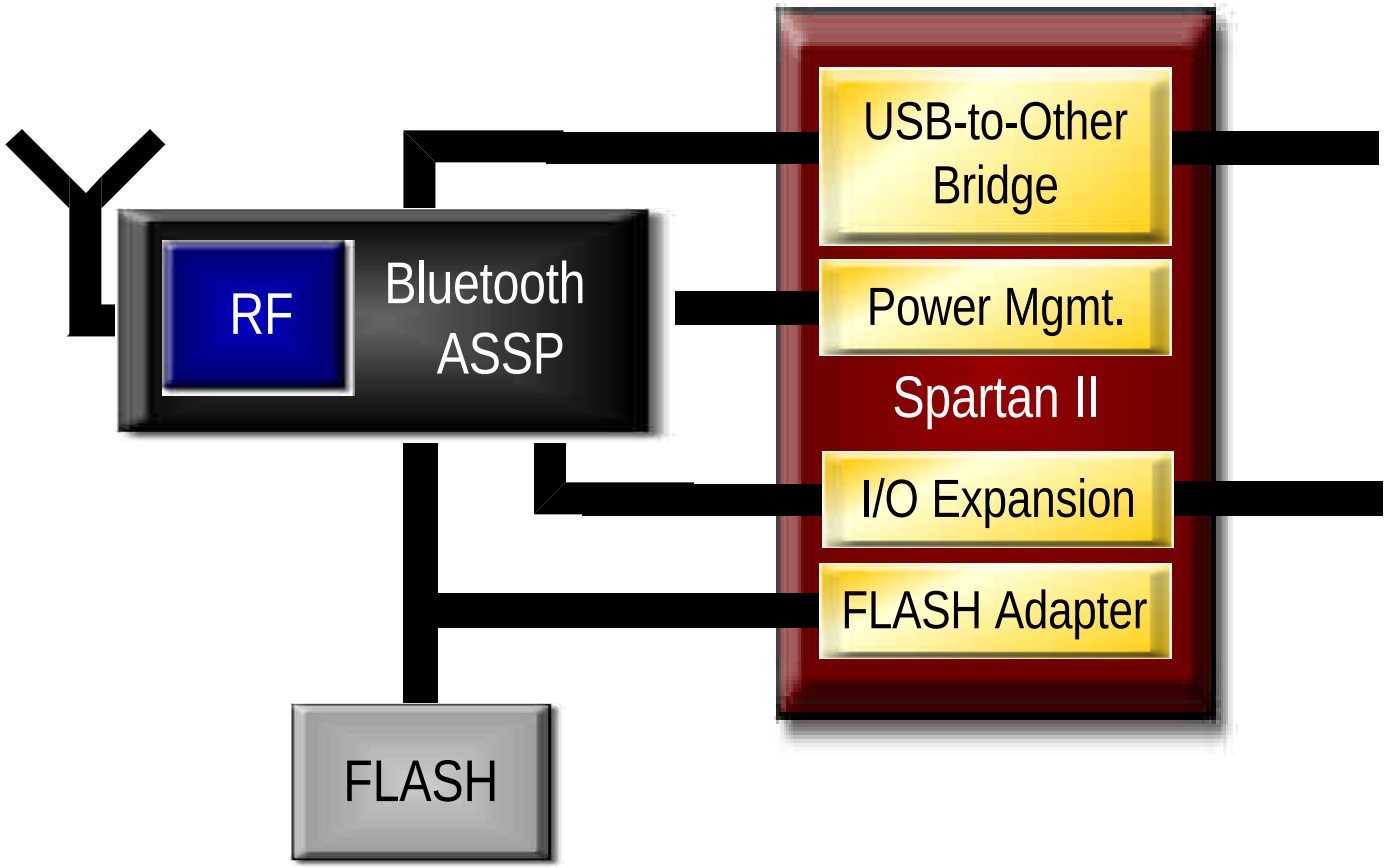
Xilinx in Bluetooth Today (5)

Spartan II Component Integration, Power Management, and HCI Bridging



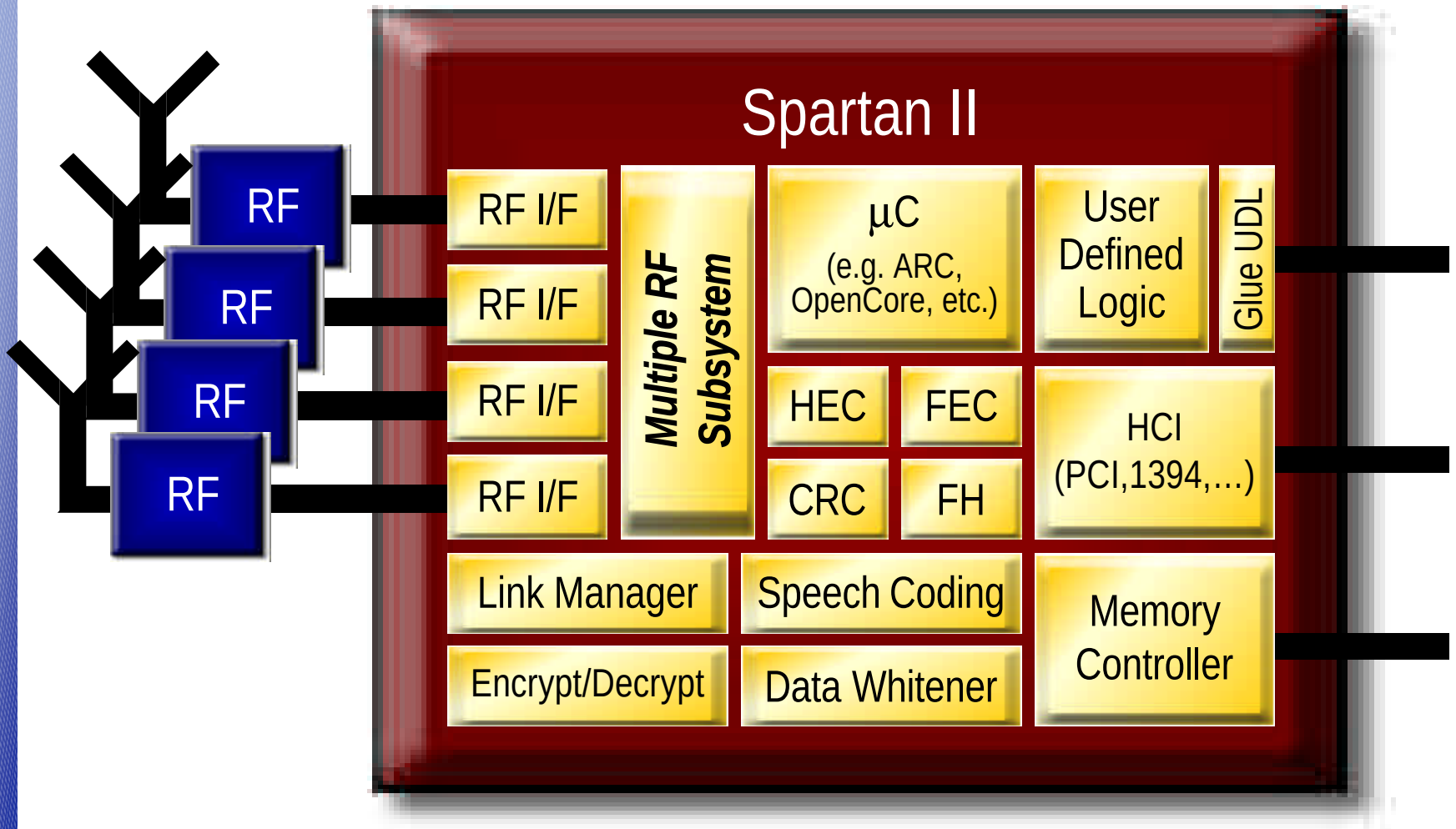
Xilinx in Bluetooth Today (6)

Spartan II Component Integration, Power Management, HCI Bridging, and System Expansion



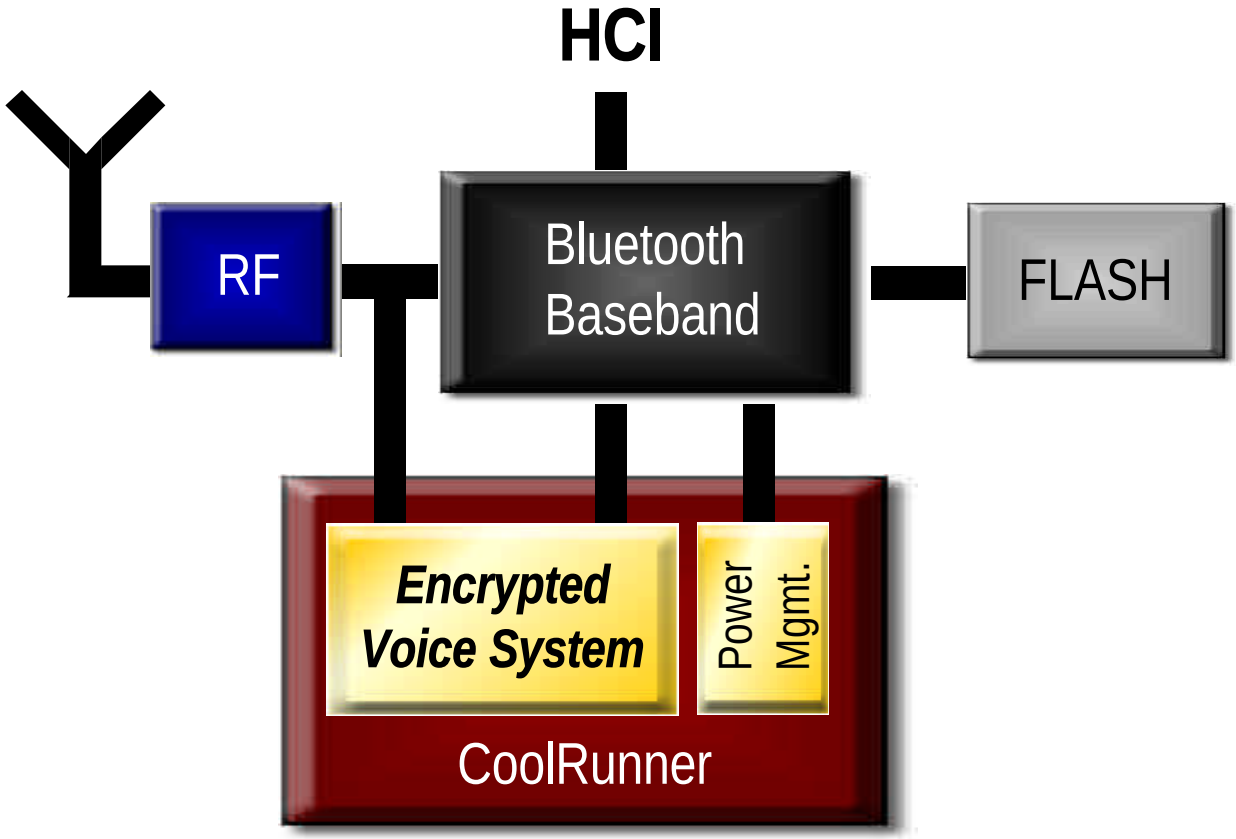
Xilinx in Bluetooth Tomorrow (1)

Spartan II Custom Baseband with Multiple RFs



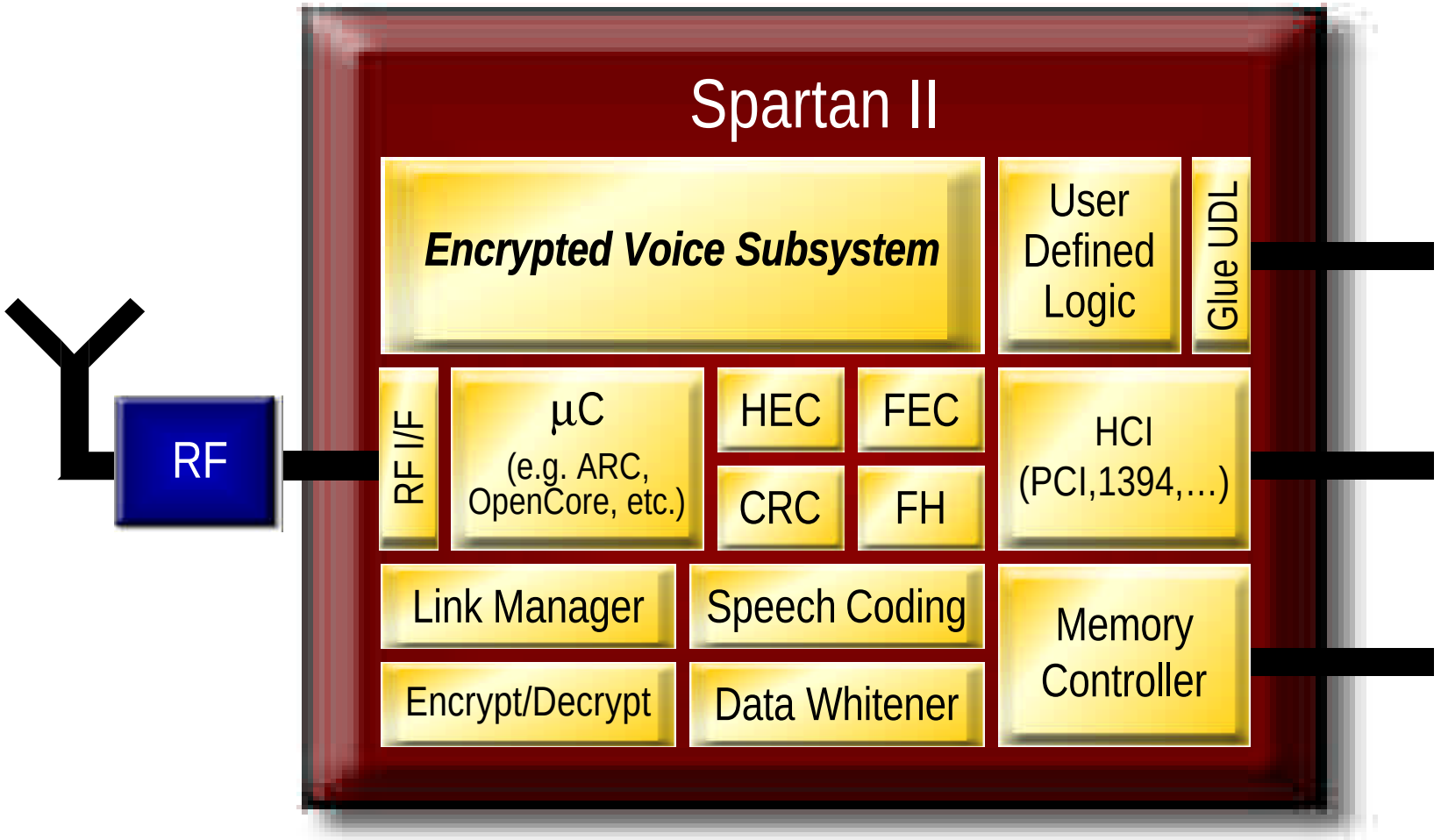
Xilinx in Bluetooth Tomorrow (2)

CoolRunner with Power Management and Custom Voice Encryption Extension



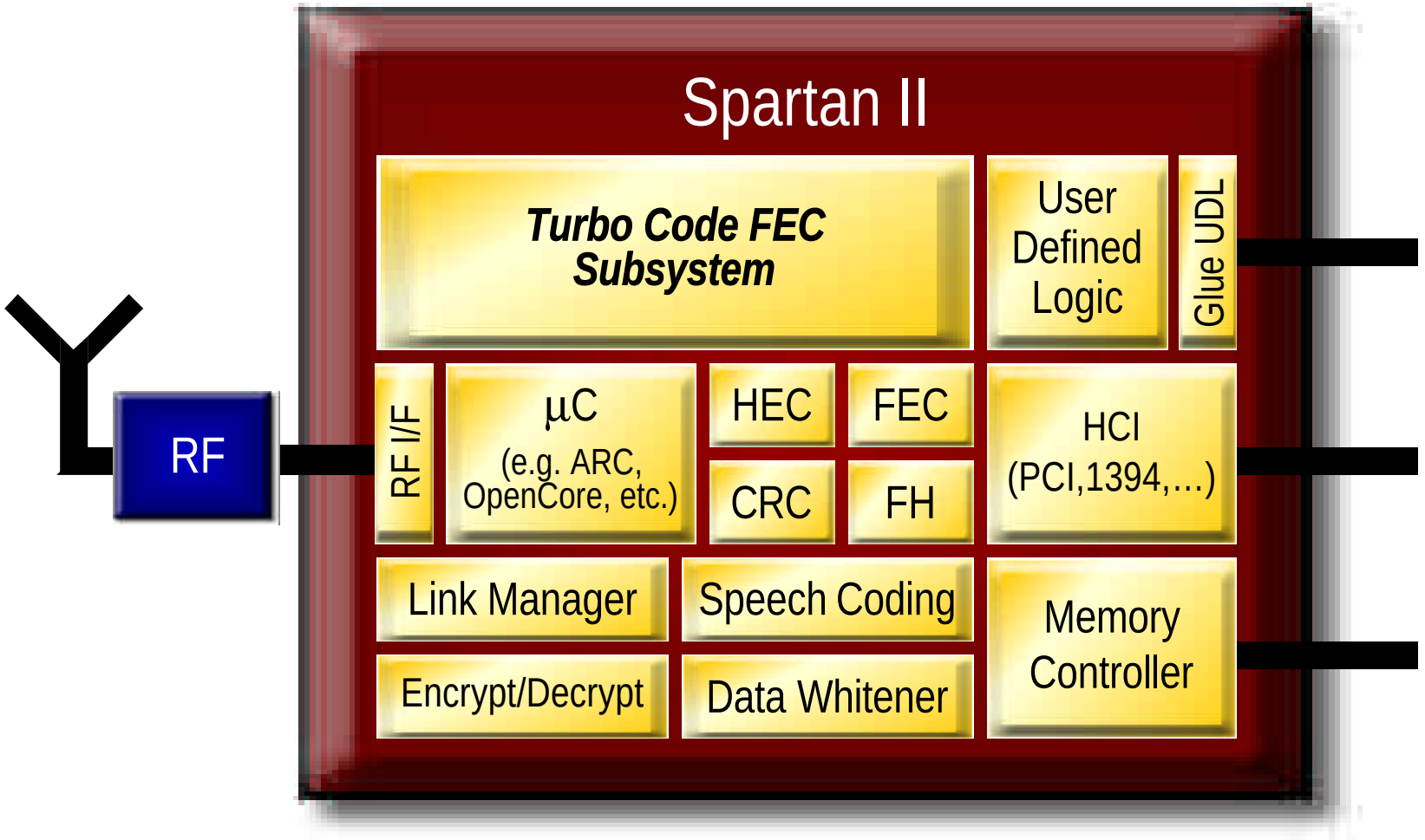
Xilinx in Bluetooth Tomorrow (3)

Spartan II Baseband with Custom Voice Encryption Extension



Xilinx in Bluetooth Tomorrow (4)

Spartan II Baseband with Custom FEC



So Who Is Bluetooth?

- Nine Promoters

Founders Y2K Additions

- And over *2000* additional SIG members

Bluetooth Conclusions

- Bluetooth is a uniquely positioned wireless solution
  - Focused primarily on short range
  - Targets modest but acceptable performance
  - Can operate at very low power
  - Has lots of utility designed in
    - Support for voice and data
    - Personal Area Networking
    - Roaming
    - Complex topologies
  - Features a very robust protocol

And targeted at *HIGH VOLUME* applications!!!

Extra

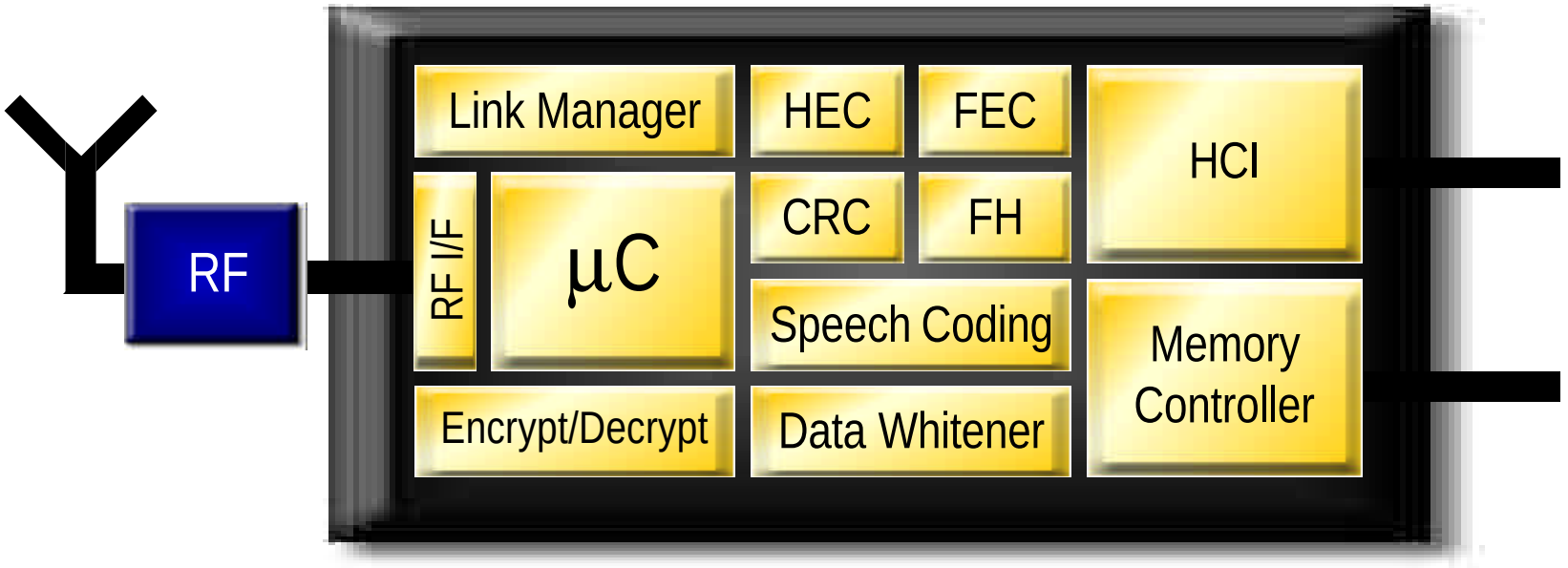
Top Bluetooth Opportunities

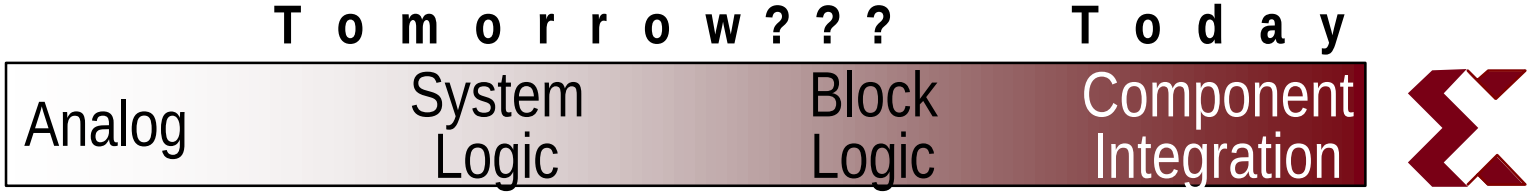
Existing Xilinx Design Wins

- Consumer Electronics
  - Diamond Multimedia
  - I-Jam
  - Philips
  - Tandberg
  - B & O
  - Kodak
  - Polaroid
  - Sony
  - Acer
  - Hitachi
  - Toshiba
  - Pioneer
  - Citizen
- Printers/Scanners
  - Xerox
  - IBM
  - Agfa
  - Agilent
  - Hitachi
- Wireless Infrastructure & Broadband Access Points
  - Cisco
  - Nortel
  - Lucent
  - Alcatel
  - SMC Networks
  - Ericsson
  - Metricom
  - Fujitsu
  - Sierra Wireless
  - Teles
  - Tellabs
  - LGIC
  - Samsung
  - Broadcom
  - Siemens
  - Adtran
  - Westell
- Set top boxes
  - GI/Motorola
  - Pace Micro
  - Sagem
  - Sony
  - GPE Technology
  - Axcent
  - Roxus
  - Sharp
  - Replay
  - Philips
  - Acer
- Handhelds
  - Palm
  - Lucent
  - Siemens
  - Agilent
  - Lockheed Martin

Xilinx in Bluetooth

Opportunities for Spartan-II and CoolRunner





Where to Find Xilinx Opportunities

CoolRunner

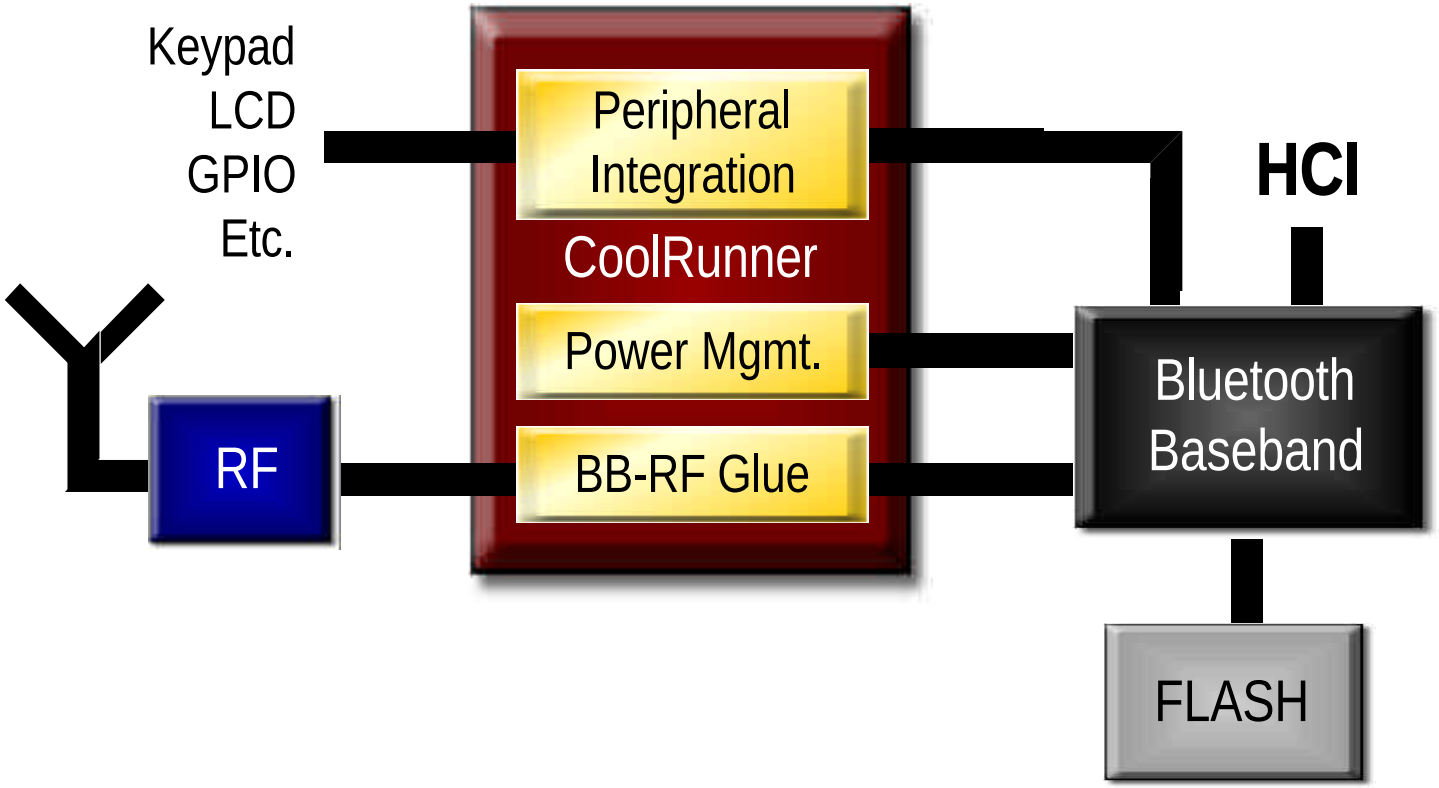
- Low-Power system integration applications
  - Handheld especially

Spartan-II

- Bluetooth enabled versions of existing computer, communications, and consumer products
  - Leverage existing design-ins
    - Set top box, MP3, digital modems, printers, gaming consoles, etc.

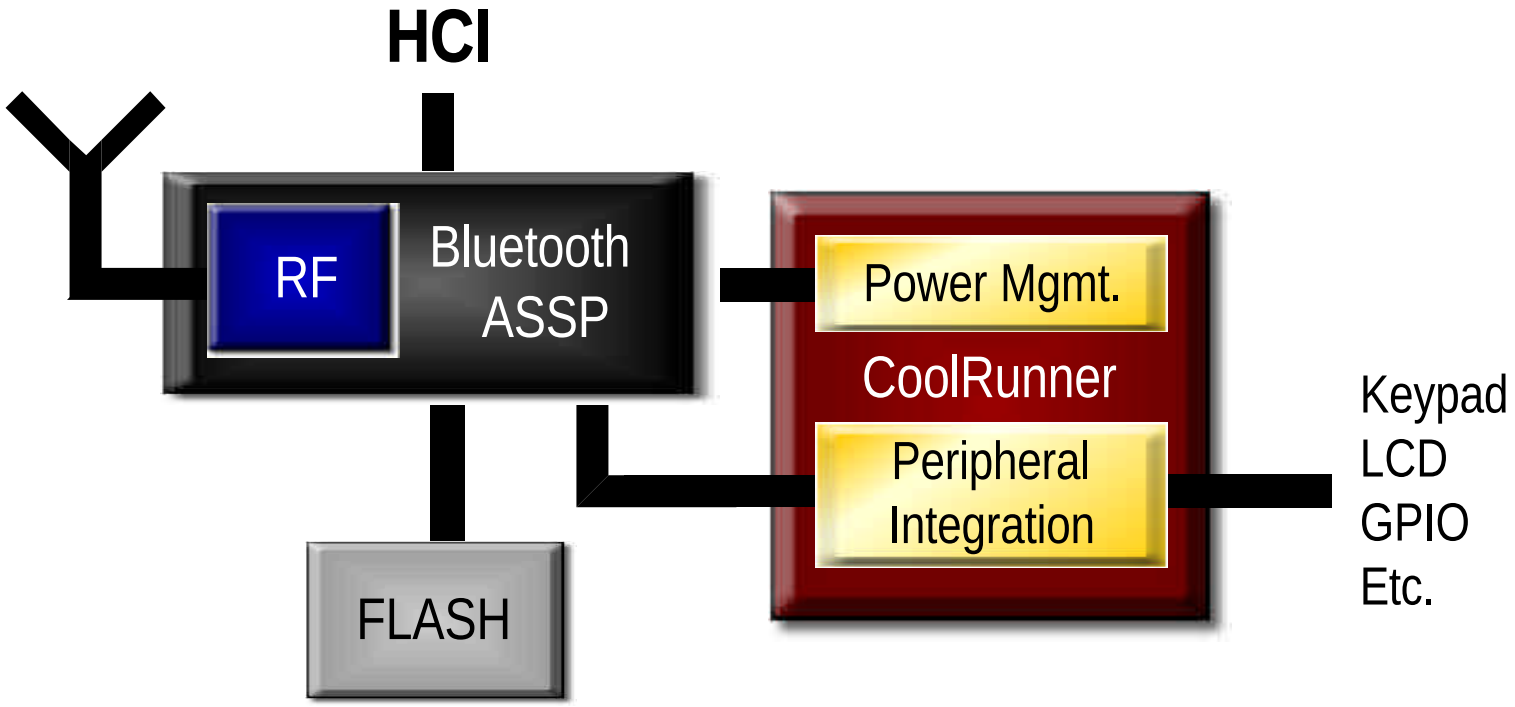
Xilinx in Bluetooth Today (1)

CoolRunner Peripheral Integration, Power Management, and Component Integration



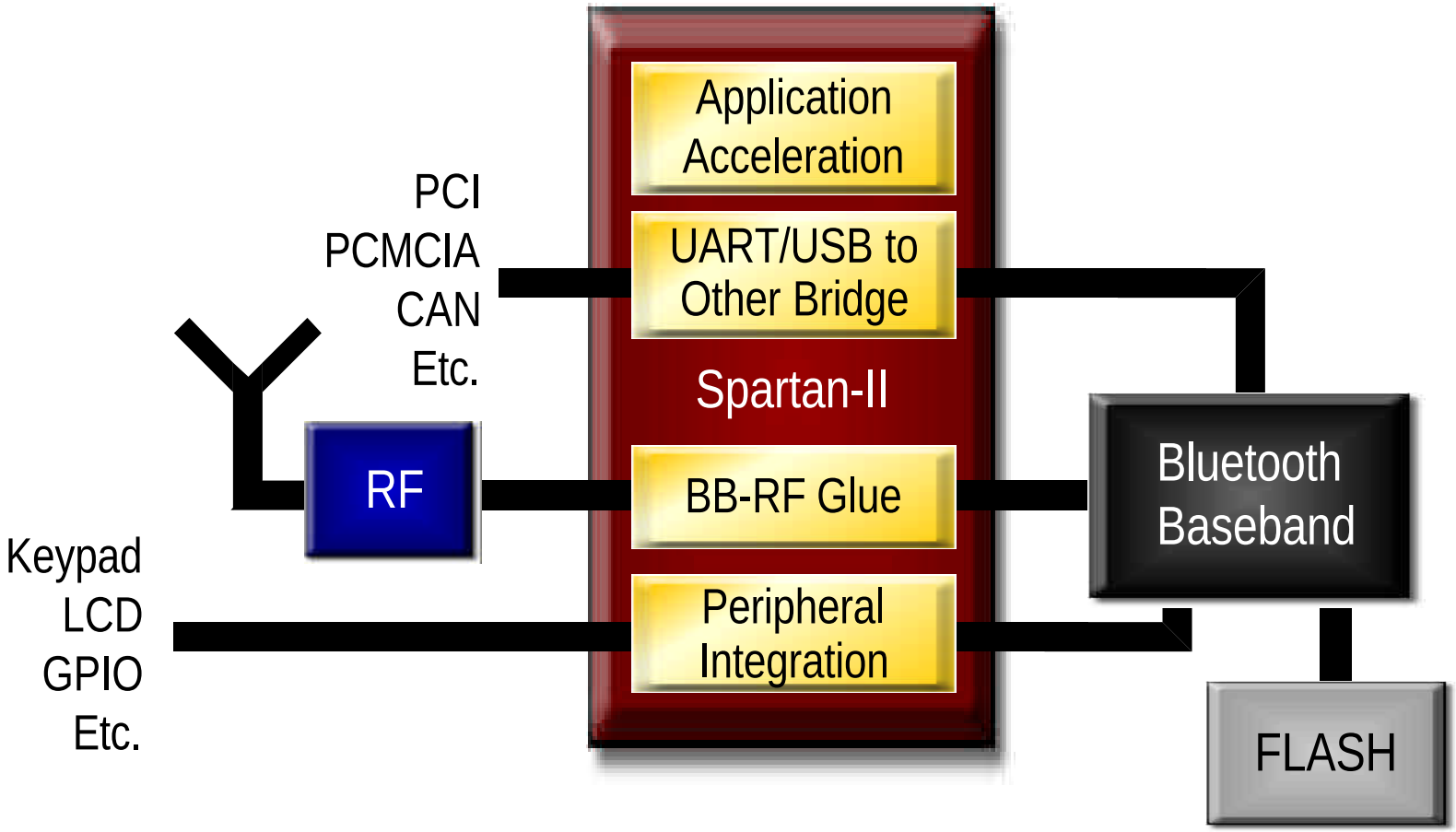
Xilinx in Bluetooth Today (2)

CoolRunner Power Management and Peripheral Integration



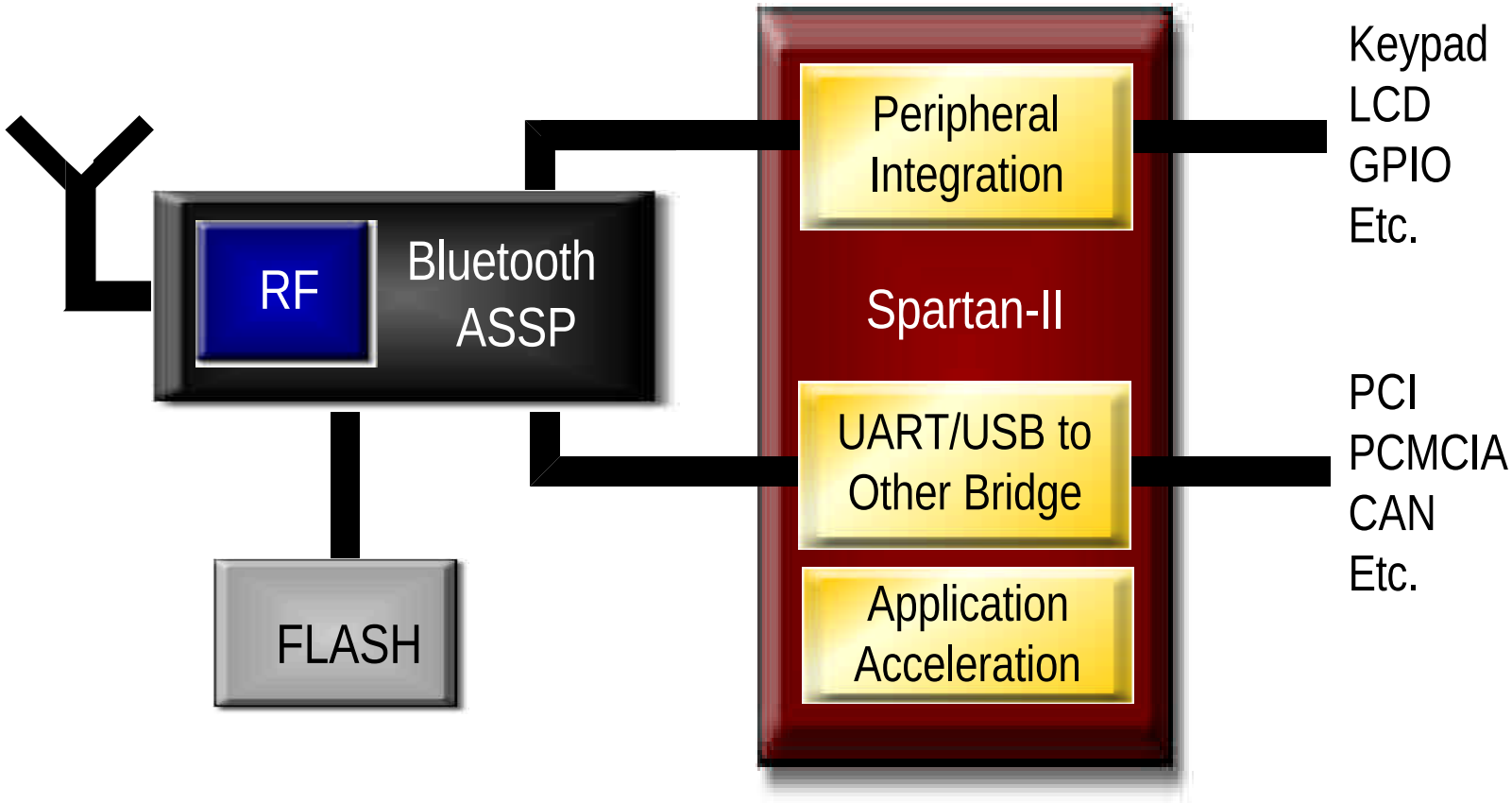
Xilinx in Bluetooth Today (3)

Spartan-II Application Acceleration, HCI Bridging, Component Integration, and Peripheral Integration



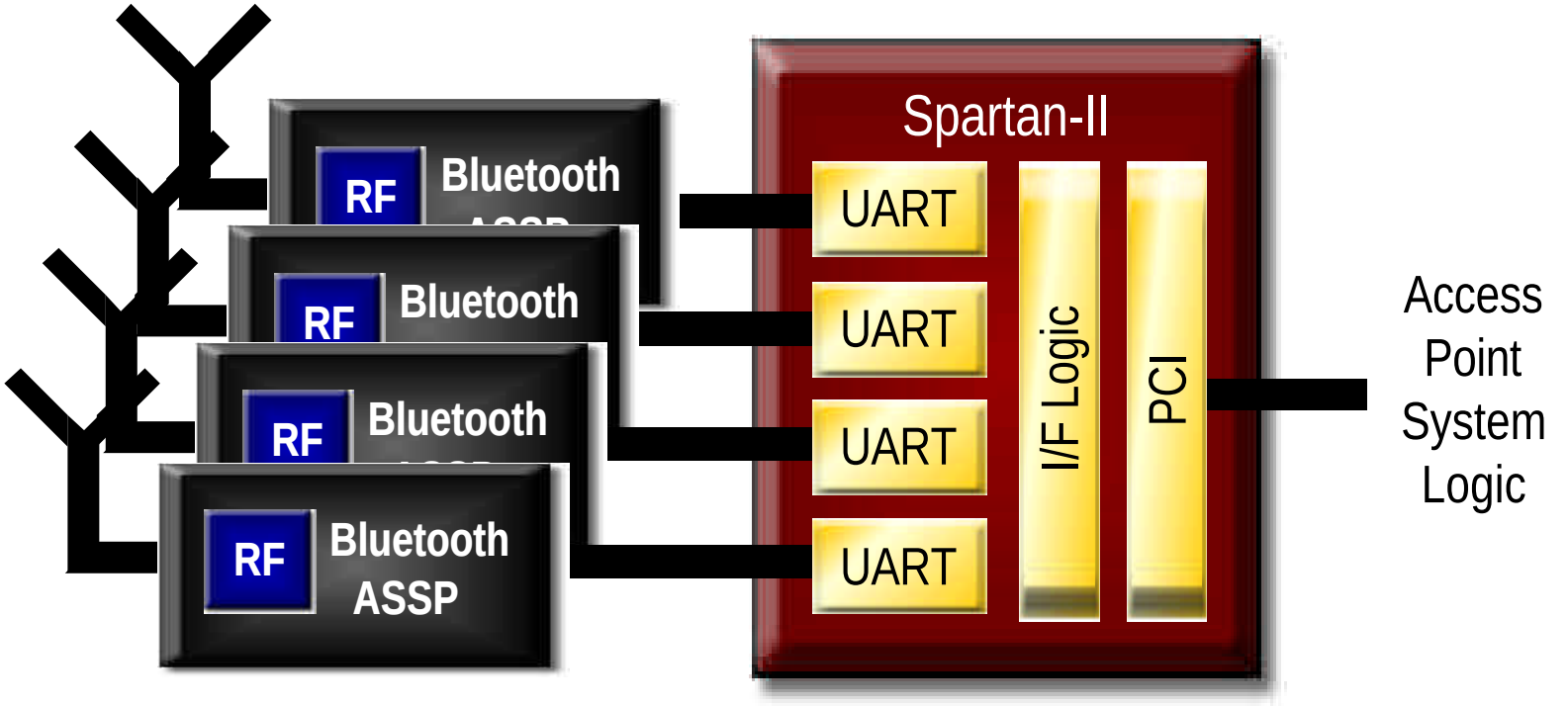
Xilinx in Bluetooth Today (4)

Spartan-II Peripheral Integration, HCI Bridging, and Application Acceleration



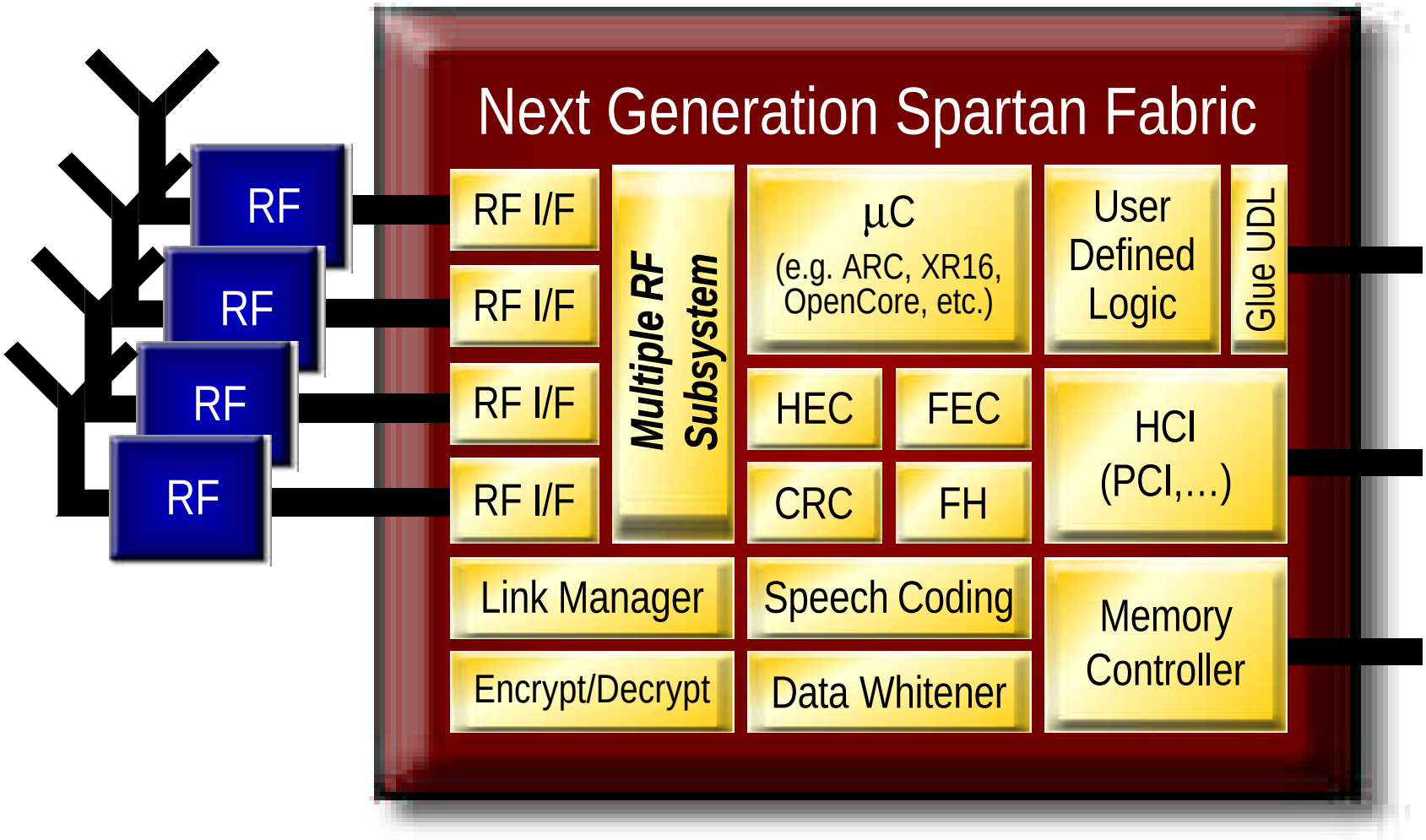
Xilinx in Bluetooth Today (5)

Spartan-II Multi-Bluetooth Controller Subsystem



Xilinx in Bluetooth Tomorrow???

Integrated Baseband with Multi-RF



Xilinx in Bluetooth Tomorrow???

Integrated Baseband with Enhanced Capabilities