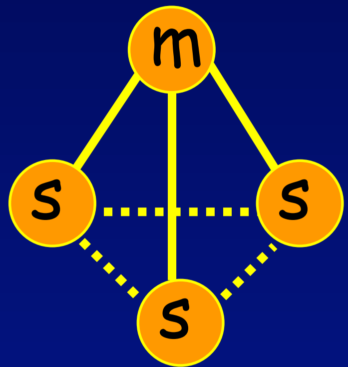

Networking over Bluetooth:

overview and issues

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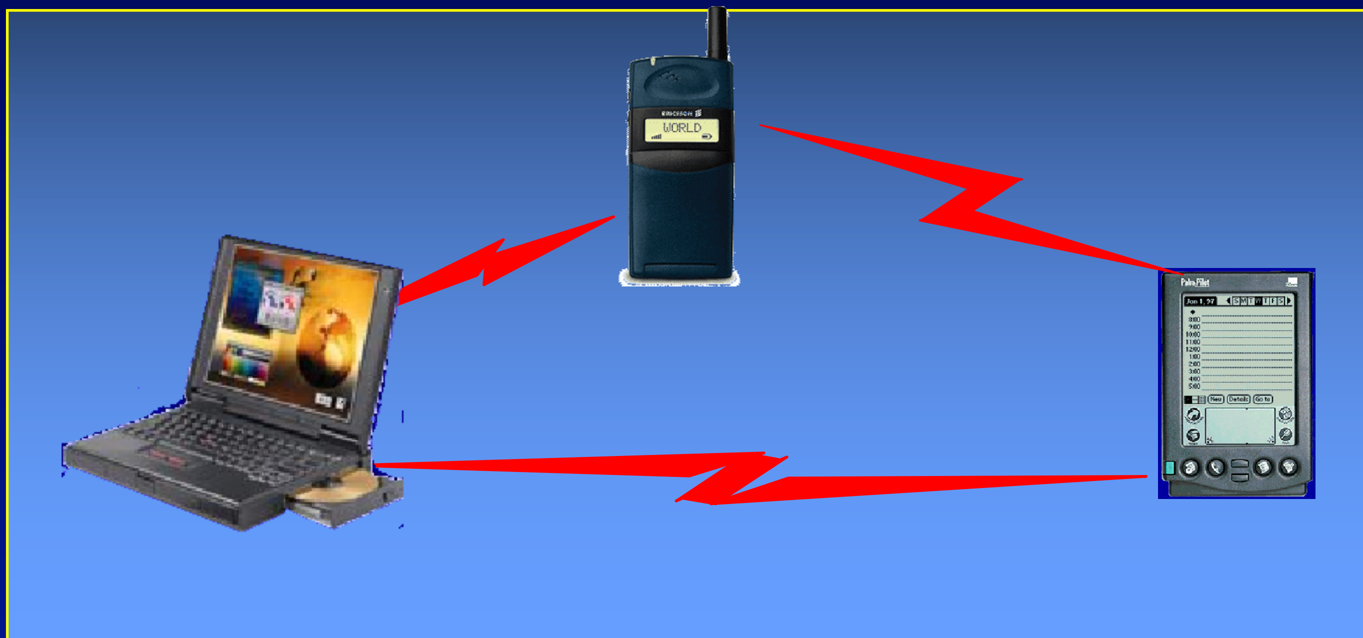
IAB Wireless Workshop

Feb 29 - March 2, 2000

Sunnyvale, CA

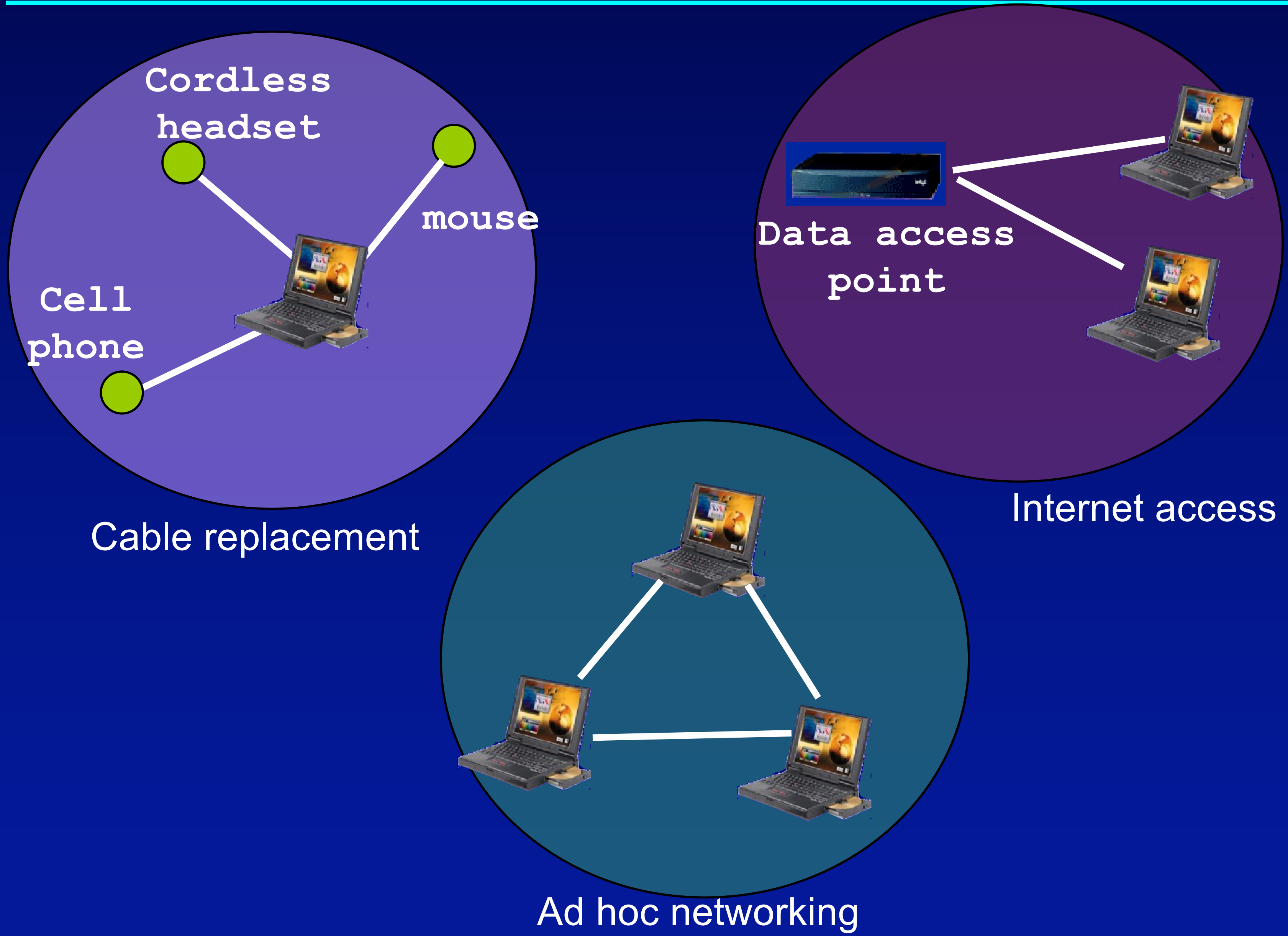
Bluetooth



- A cable replacement technology
- 1 Mb/s symbol rate
- Range 10+ meters
- Single chip radio + baseband
    - at low power & low price point

Why not use Wireless LANs?
- power
- cost

Value proposition of Bluetooth



Bluetooth working group history

- February 1998: The Bluetooth SIG is formed
  - promoter company group: Ericsson, IBM, Intel, Nokia, Toshiba
- May 1998: The Bluetooth SIG goes “public”
- July 1999: 1.0A spec (>1,500 pages) is published
- December 1999: ver. 1.0B is released
- December 1999: The promoter group increases to 9
  - 3Com, Lucent, Microsoft, Motorola
- February 2000: There are 1,500+ adopters
  - adopters "enjoy" royalty free use of the Bluetooth technology
    - products must pass Bluetooth certification

New Applications

Synchronization

User benefits

- Automatic synchronization of calendars, address books, business cards
- Push button synchronization
- Proximity operation

Cordless Headset

User benefits

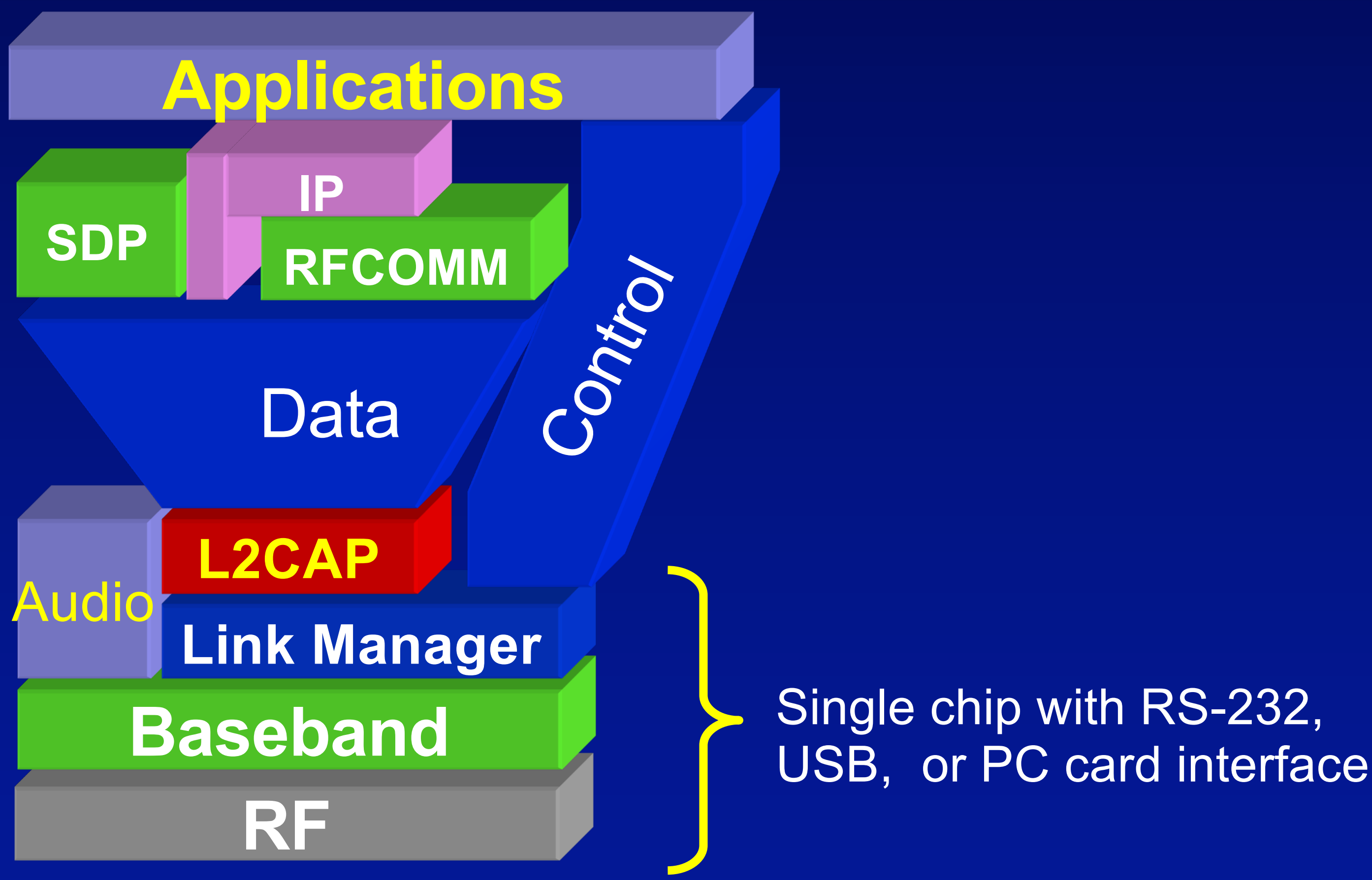
- **Multiple device access**
- **Cordless phone benefits**
- **Hand's free operation**

Usage scenarios examples

- Data Access Points
- Synchronization
- Headset
- Conference Table
- Cordless Computer
- Business Card Exchange
- Instant Postcard
- Computer Speakerphone

Bluetooth Specifications

Bluetooth Stack



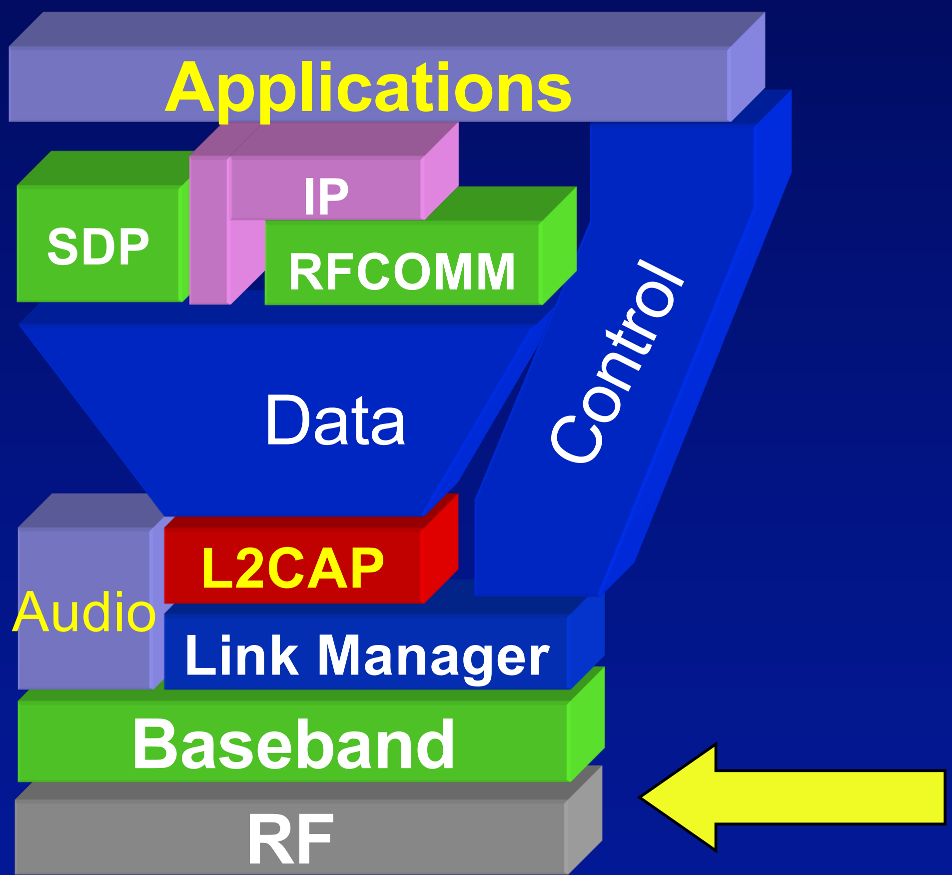
- A hardware/software/protocol description
- An application framework

Interoperability & Profiles

- A profile represents a default solution for a usage model
- Vertical slice through the protocol stack
- Basis for interoperability and logo requirements
- Each Bluetooth device supports one or more profiles

Technical Overview

Bluetooth Radio Specification



Radio

- **Low Cost**
  - Single chip radio (minimize external components)
  - Today's technology
  - Time divison duplex
- **Low Power**
  - Standby modes   Sniff, Hold, Park
  - Low voltage RF
- **Robust Operation**
  - Fast frequency hopping   1600 hops/sec
  - Strong interference protection
    - Fast ARQ
    - Robust access code
    - Forward header correction

Radio

0 dBm — Tx power

-20 — Rx power @ 10 cm

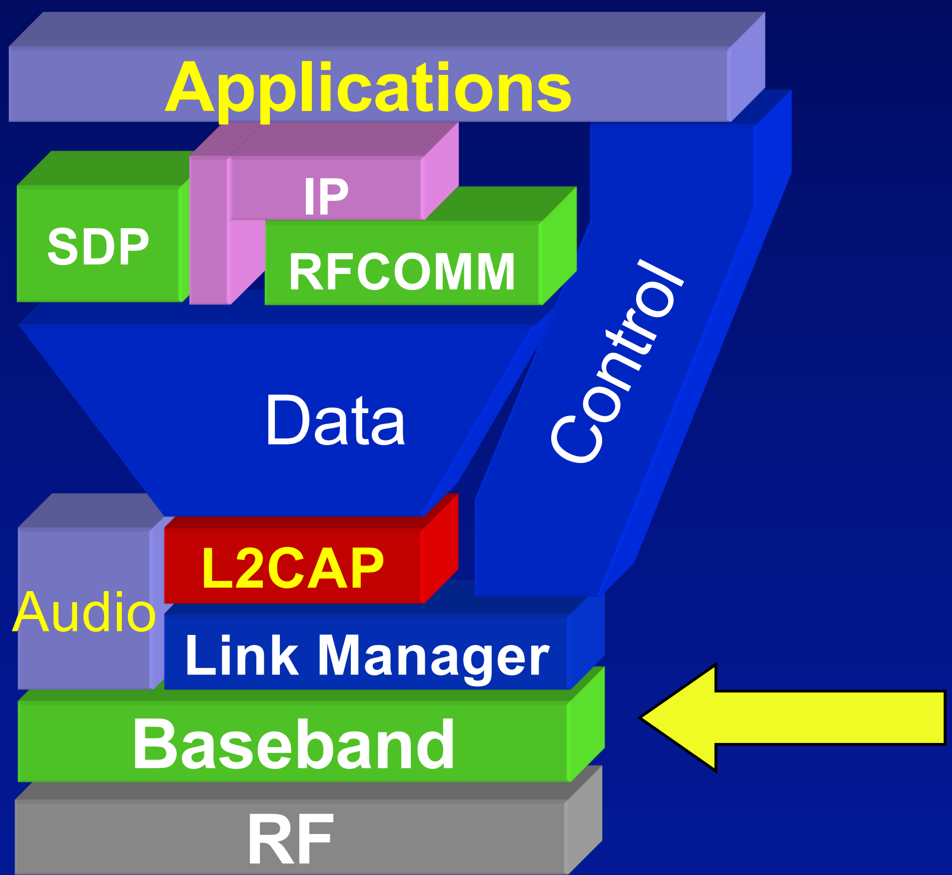
- Allow low cost low IF
- Trade sensitivity for integration
- One chip radio is possible

-70 — Rx power @ 10m

-91 — Noise floor

C/I = 21 dB

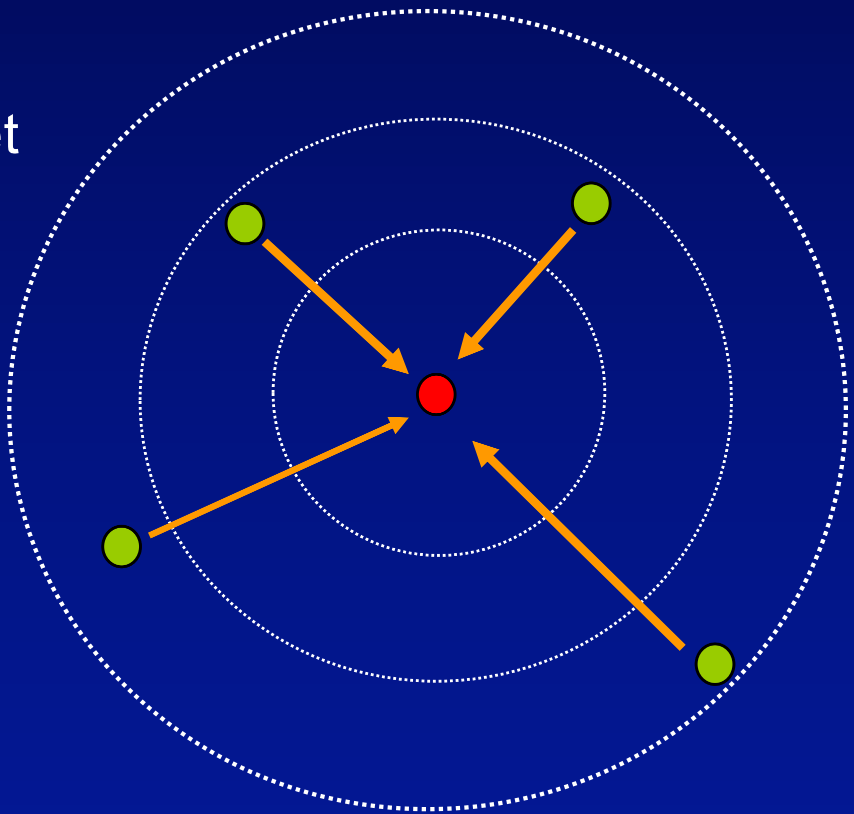
Baseband



Applications
SDP
IP
RFCOMM
Data
Control
Audio
L2CAP
Link Manager
Baseband
RF

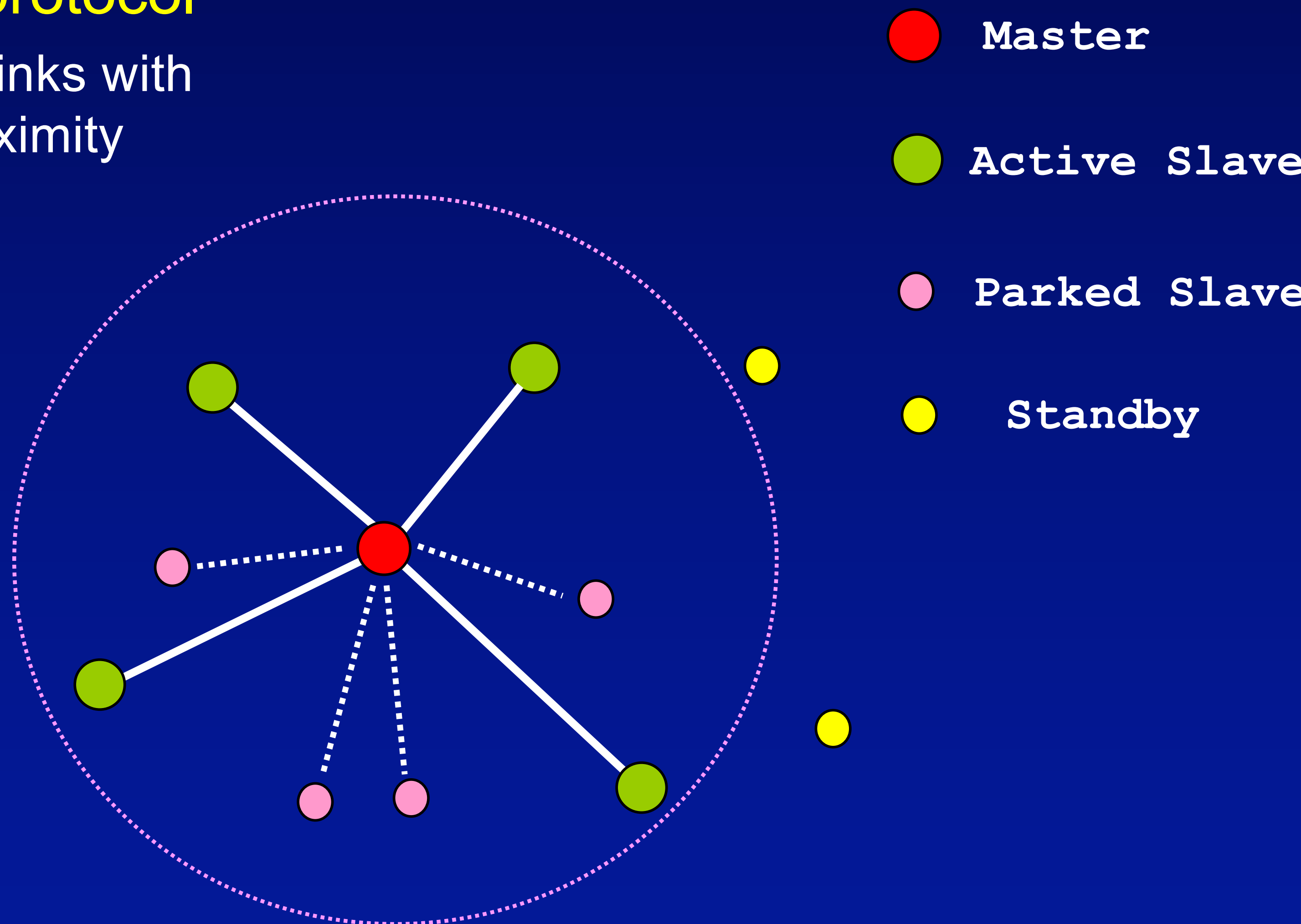
Connection Setup

- Inquiry - scan protocol
  - to lean about the clock offset and device address of other nodes in proximity



Piconet formation

- Page - scan protocol
  - to establish links with nodes in proximity

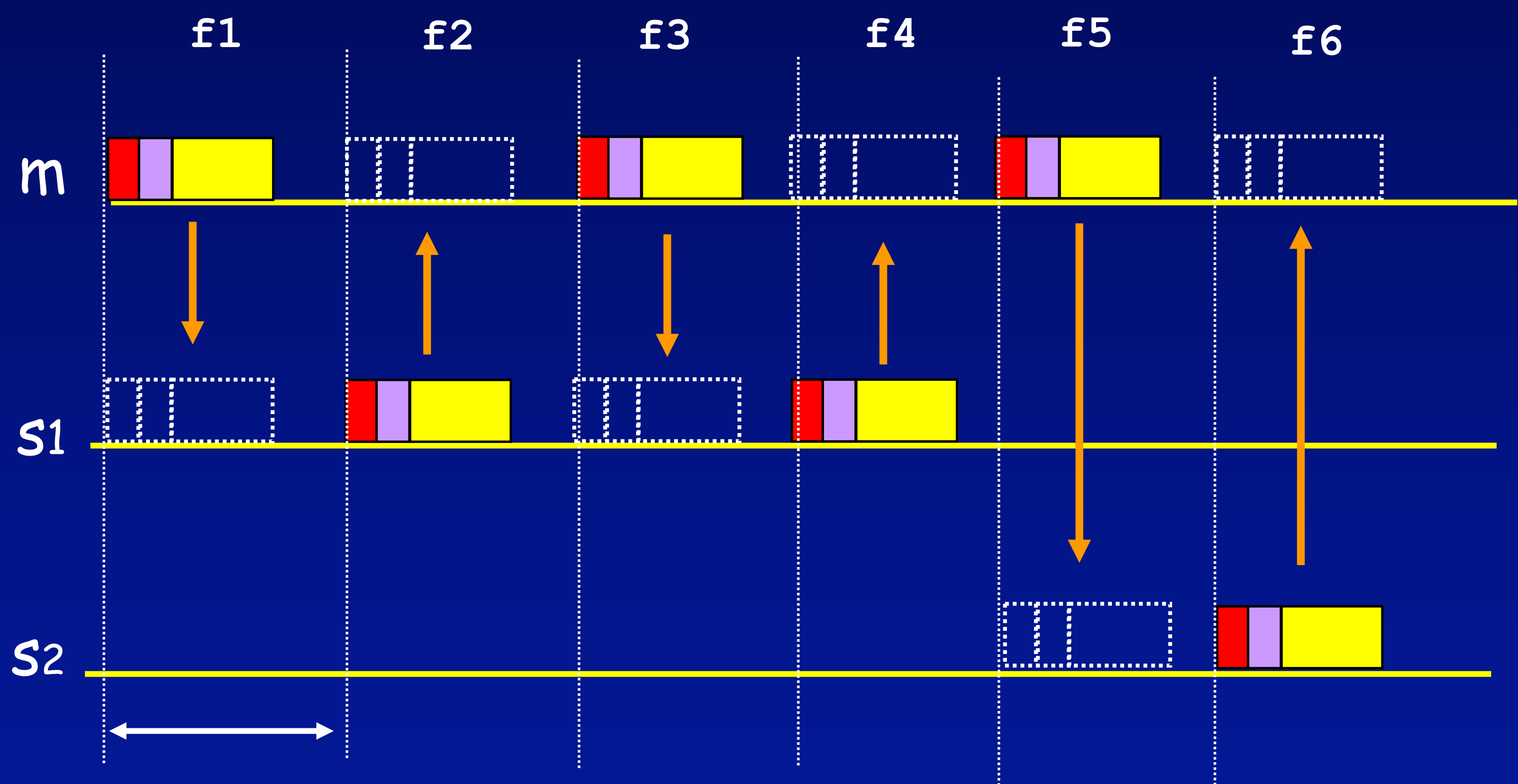


Addressing

- Bluetooth device address (BD_ADDR)
  - 48 bit IEEE MAC address
- Active Member address (AM_ADDR)
  - 3 bits active slave address
  - all zero broadcast address
- Parked Member address (PM_ADDR)
  - 8 bit parked slave address

Piconet channel

FH/TDD

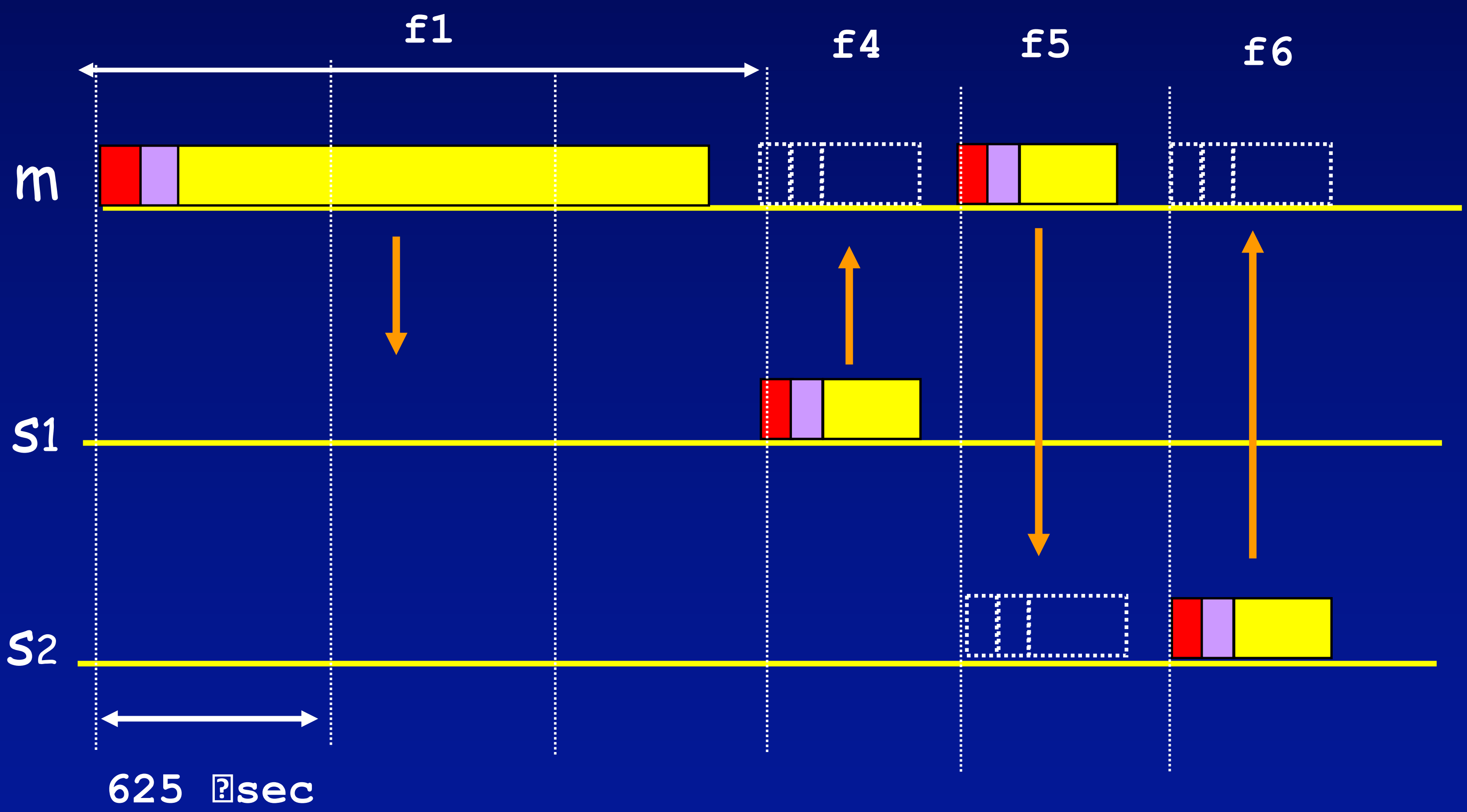


625 μsec

1600 hops/sec

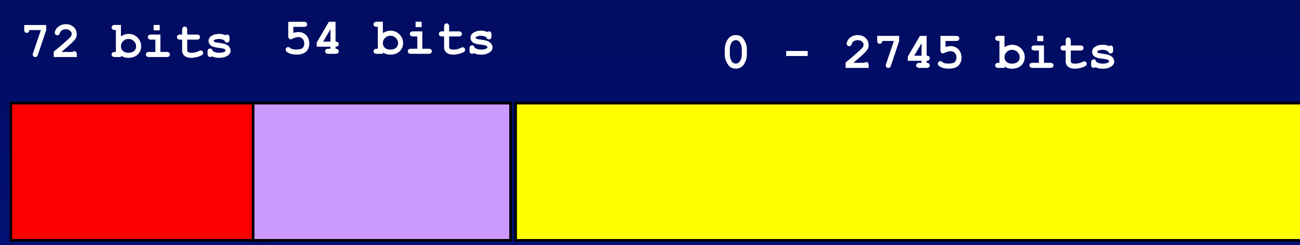
Multi slot packets

FH/TDD



Data rate depends on type of packet

Packet Format



Access code
↓
Synchronization
identification
Filtering

Header
↓
Address
Packet Type
Flow control
ARQ
SEQN
HEC

Payload

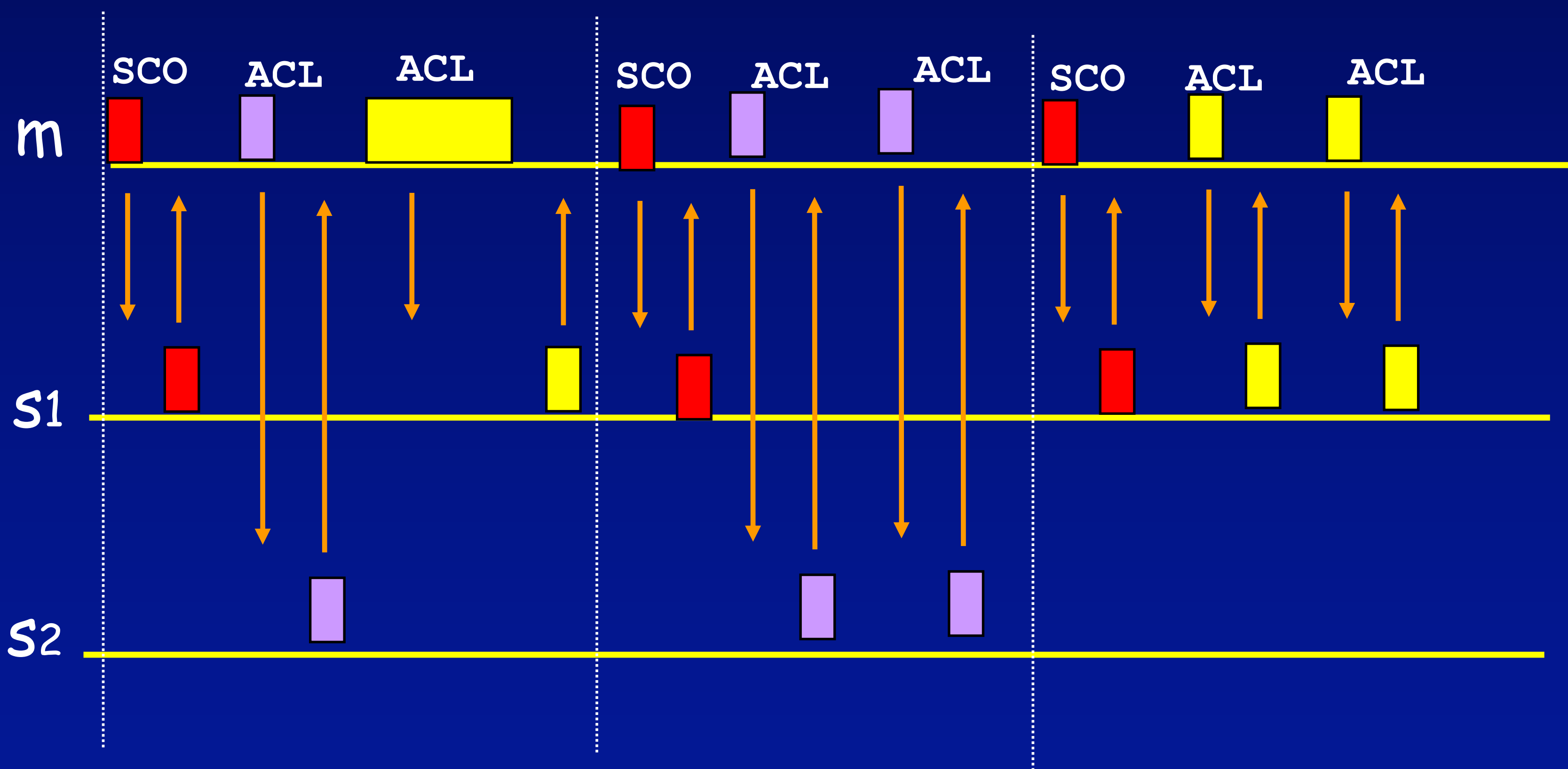
Error correction
1/3 rate FEC
2/3 rate FEC
ARQ scheme for the data

Smaller than an ATM cell !
Notice that there is no protocol type field

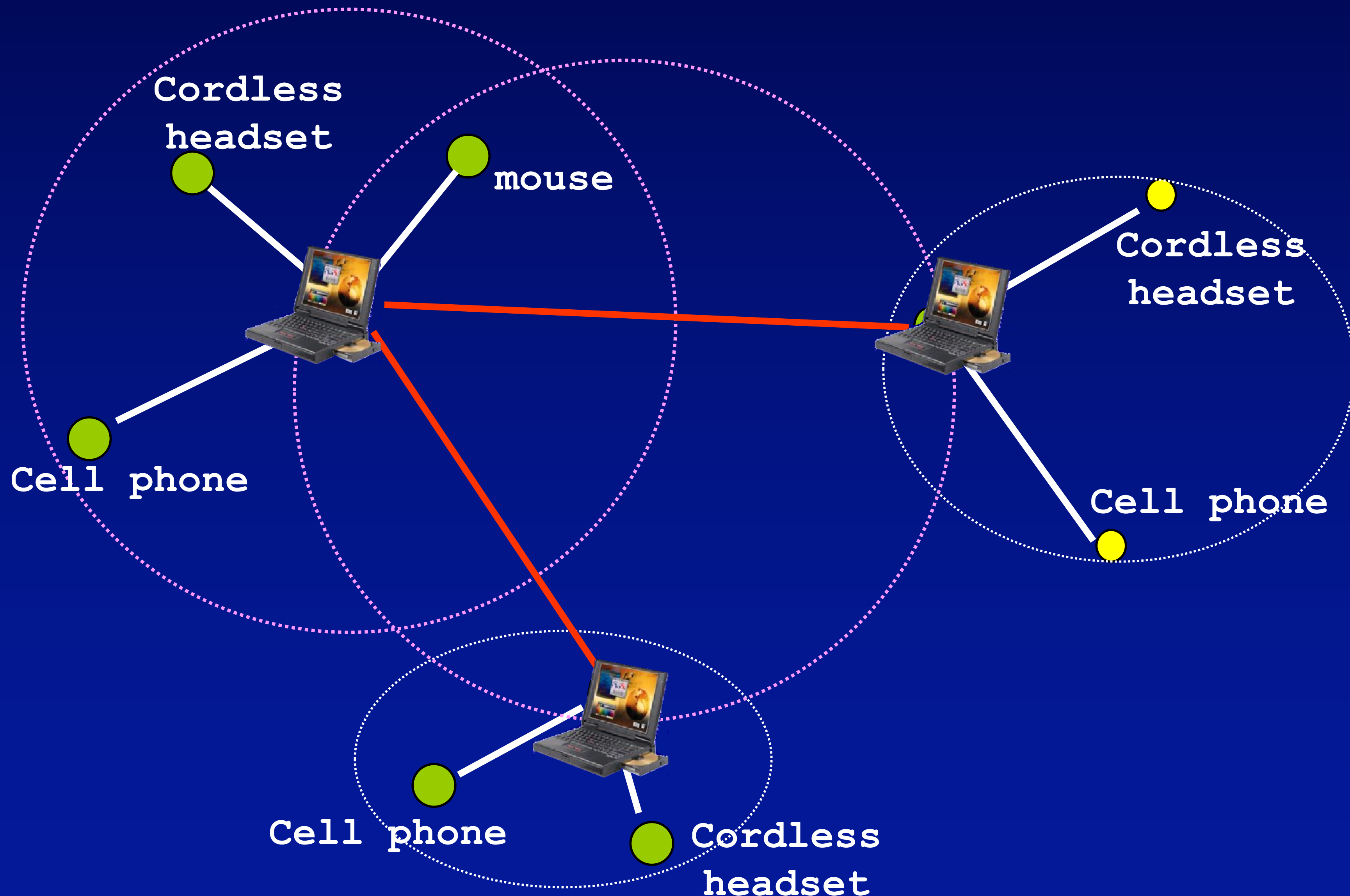
Physical Link Types

- Synchronous Connection Oriented (SCO) Link
  - slot reservation at fixed intervals
    - No ARQ, No CRC
    - FEC (optional)
    - 64 Kbps
- Asynchronous Connection-less (ACL) Link
  - Polling access method
  - ARQ, CRC
  - FEC (optional)
  - Symmetric data rate 108 - 433 Kbps
  - Asymmetric data rate up to 723 Kbps

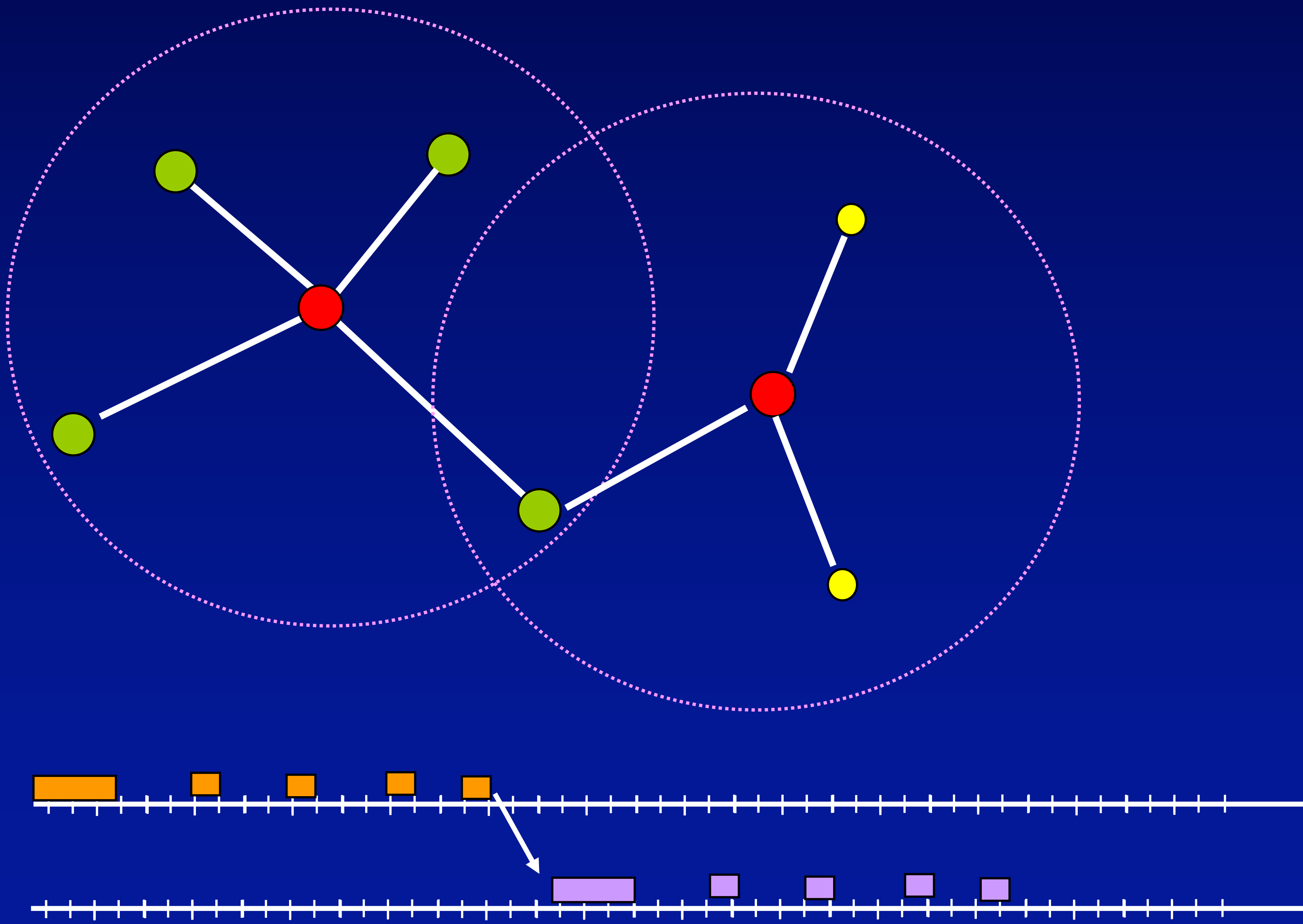
Mixed Link Example



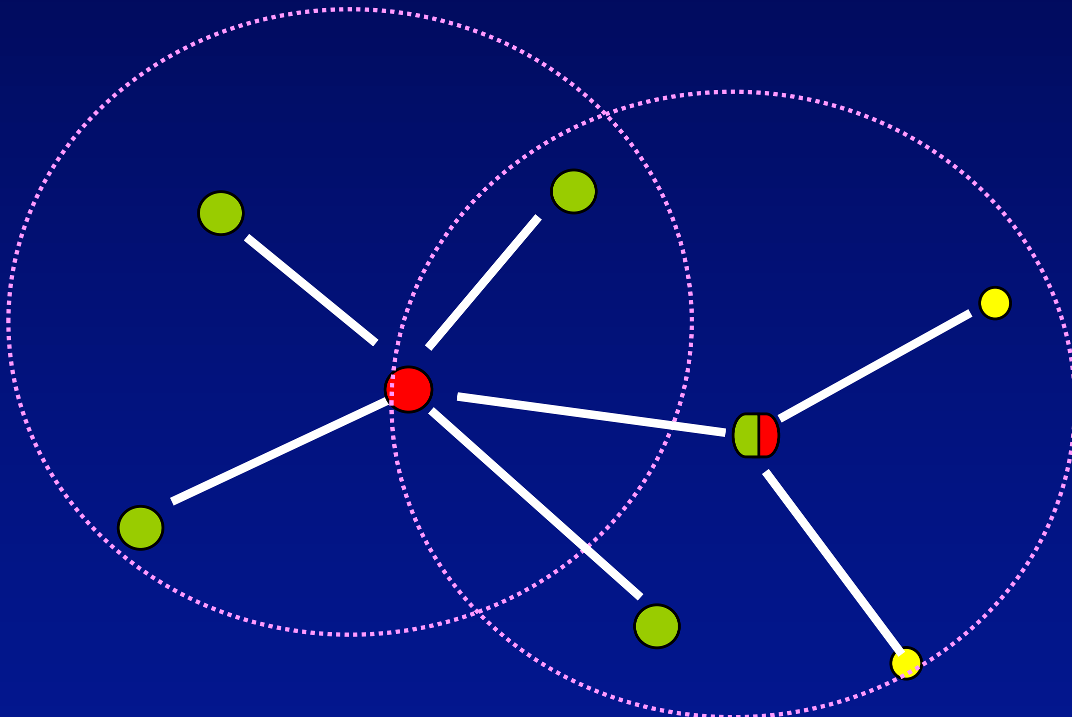
Inter piconet communication



Scatternet



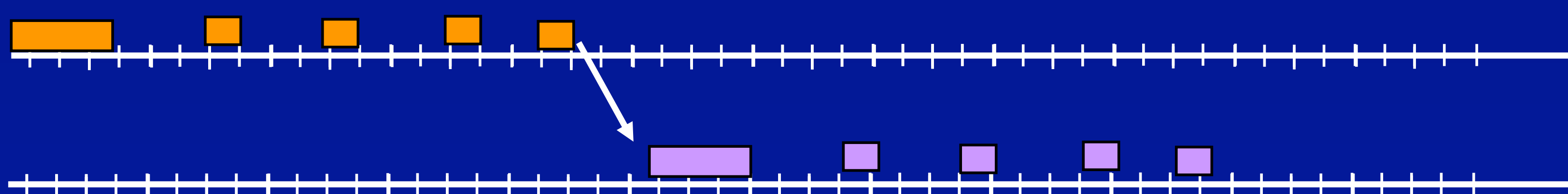
Scatternet, scenario 2



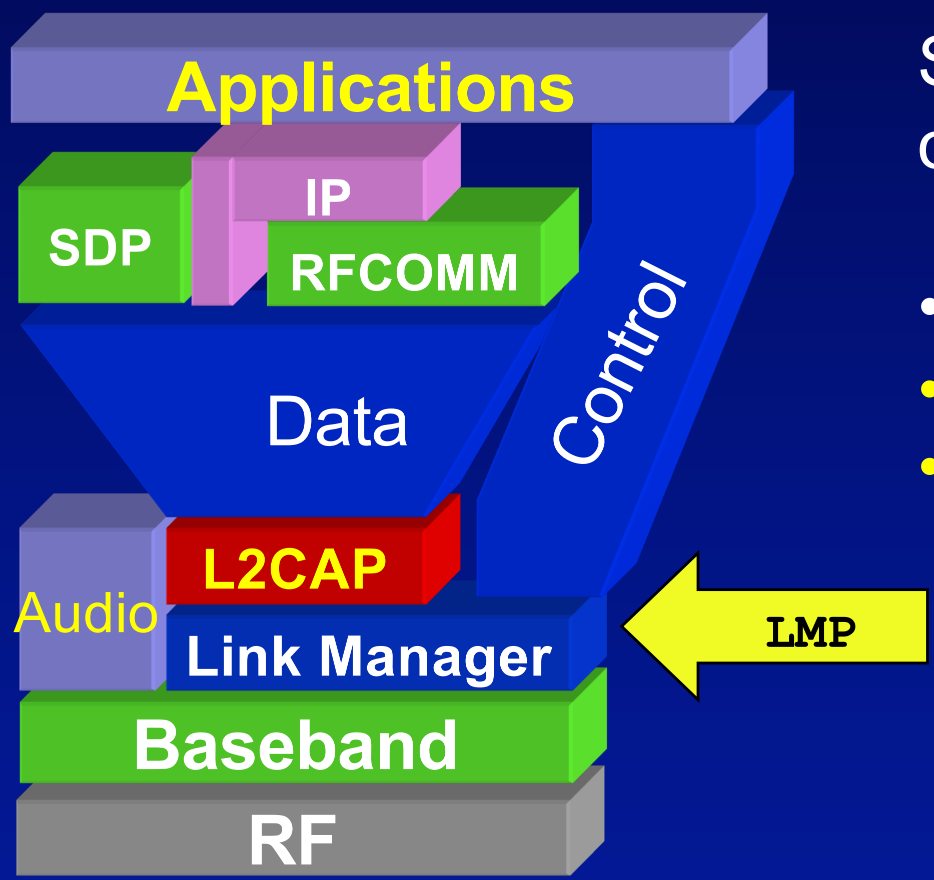
How to schedule presence in two piconets?

Forwarding delay ?

Missed traffic?



Link Manager Protocol



Setup and Management of Baseband connections

- Piconet Management
- Link Configuration
- Security

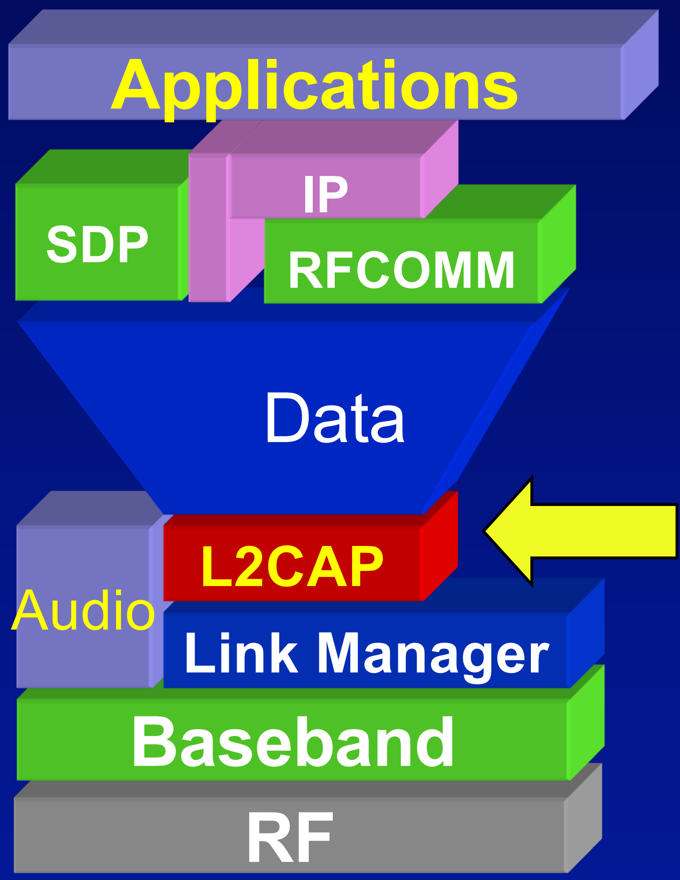
Link Manager Protocol

- Piconet Management
  - Attach and detach slaves
  - Master-slave switch
  - Establishing SCO and ACL links
  - Handling of low power modes (Sniff, Hold, Park)

- Link Configuration
  - packet type negotiation
  - power control

- Security functions
  - Authentication
  - Encryption

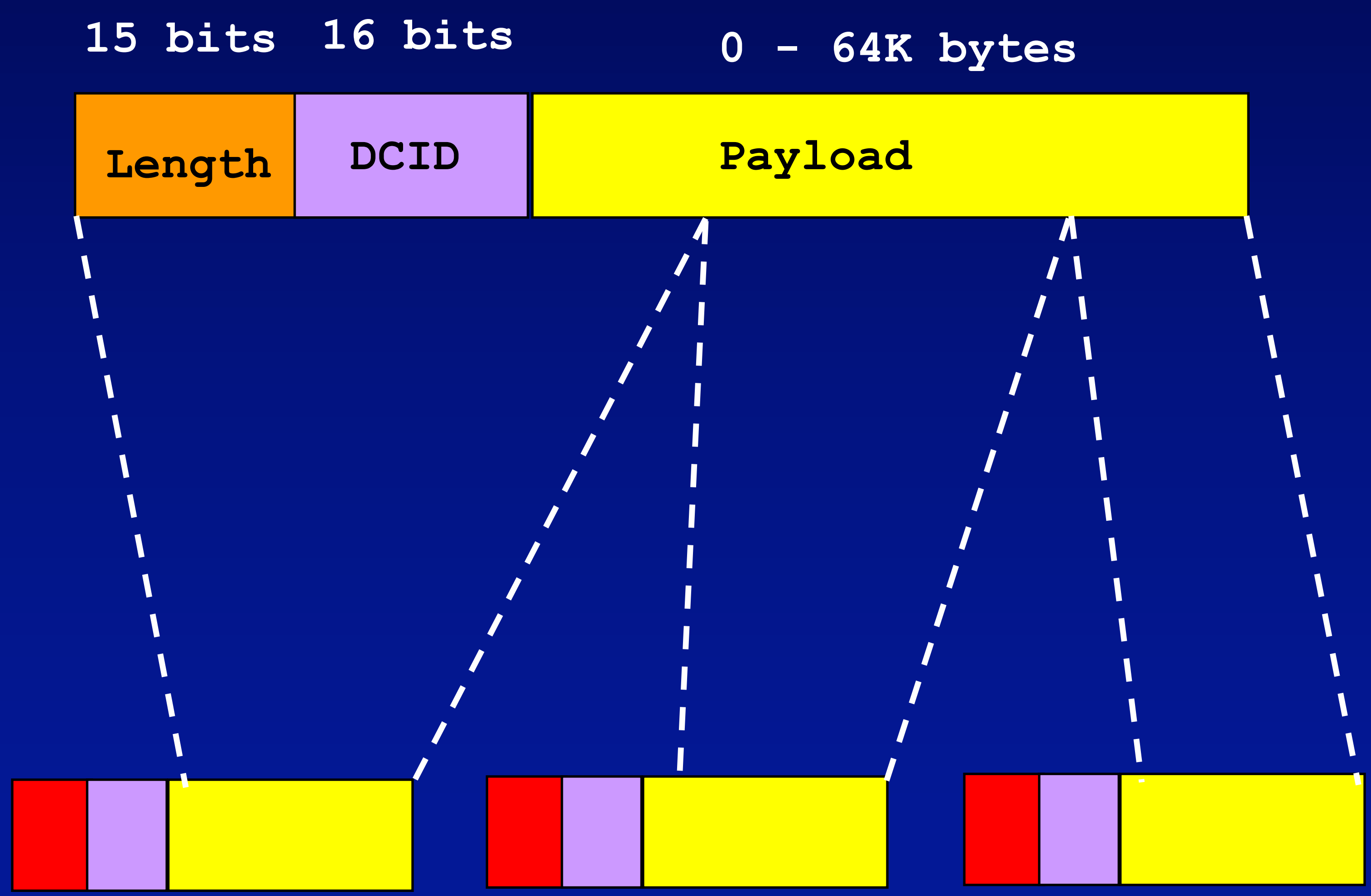
L2CAP



Logical Link Control and Adaptation Protocol

- L2CAP provides
  - Protocol multiplexing
  - Segmentation and Re-assembly
  - Quality of service negotiation
  - Group abstraction

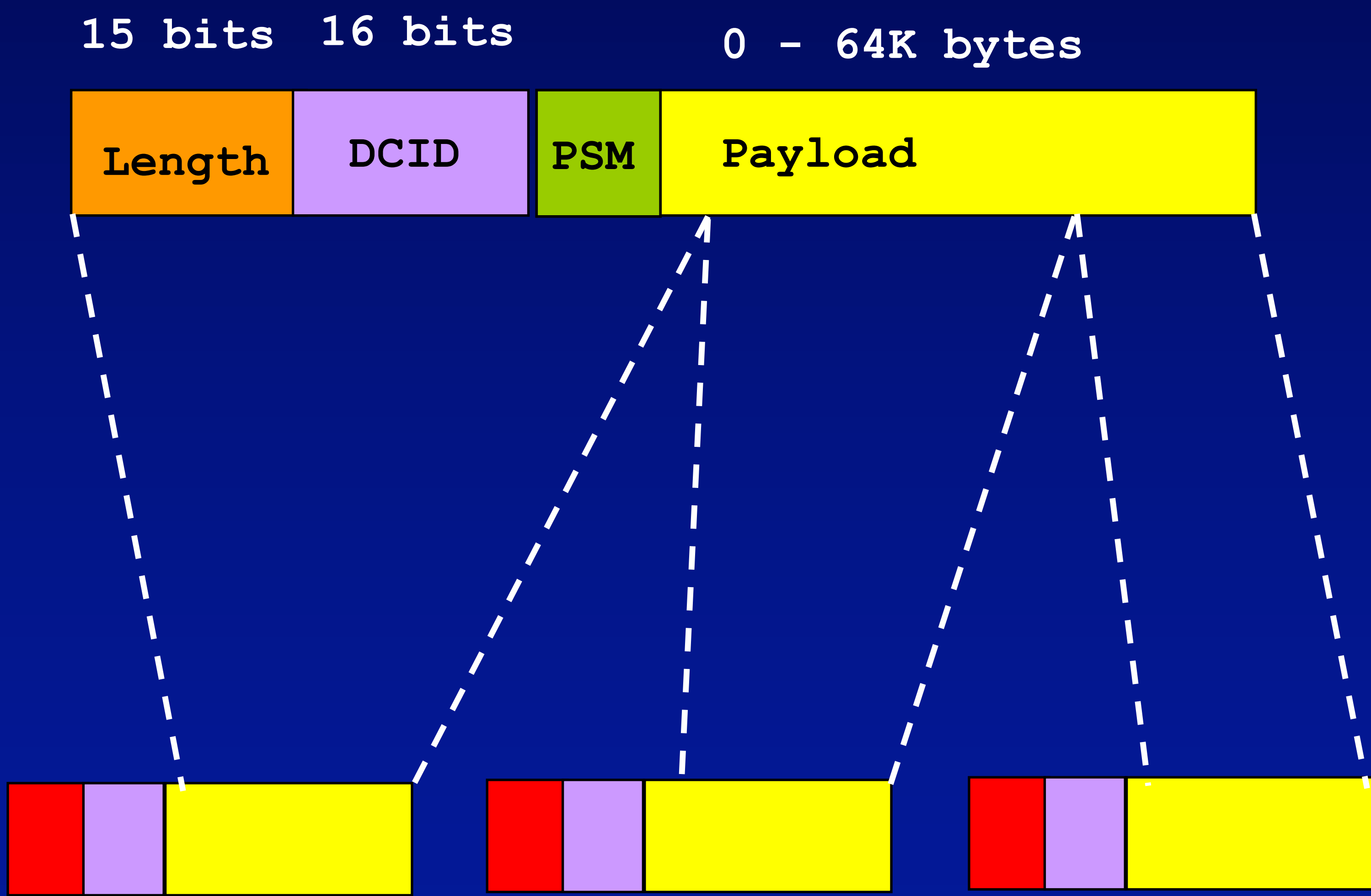
L2CAP Packet Format (CO)



Baseband packets

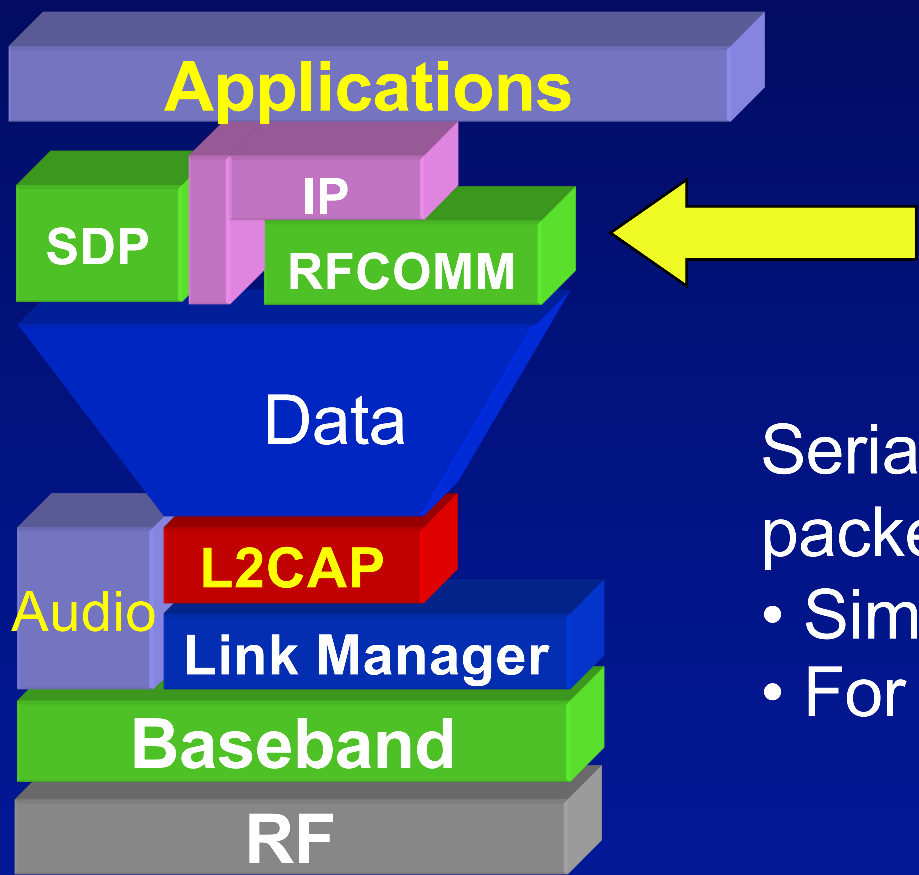
Minimum MTU is 48 bytes !
default is 672 bytes !

L2CAP Packet Format (CL)



Baseband packets

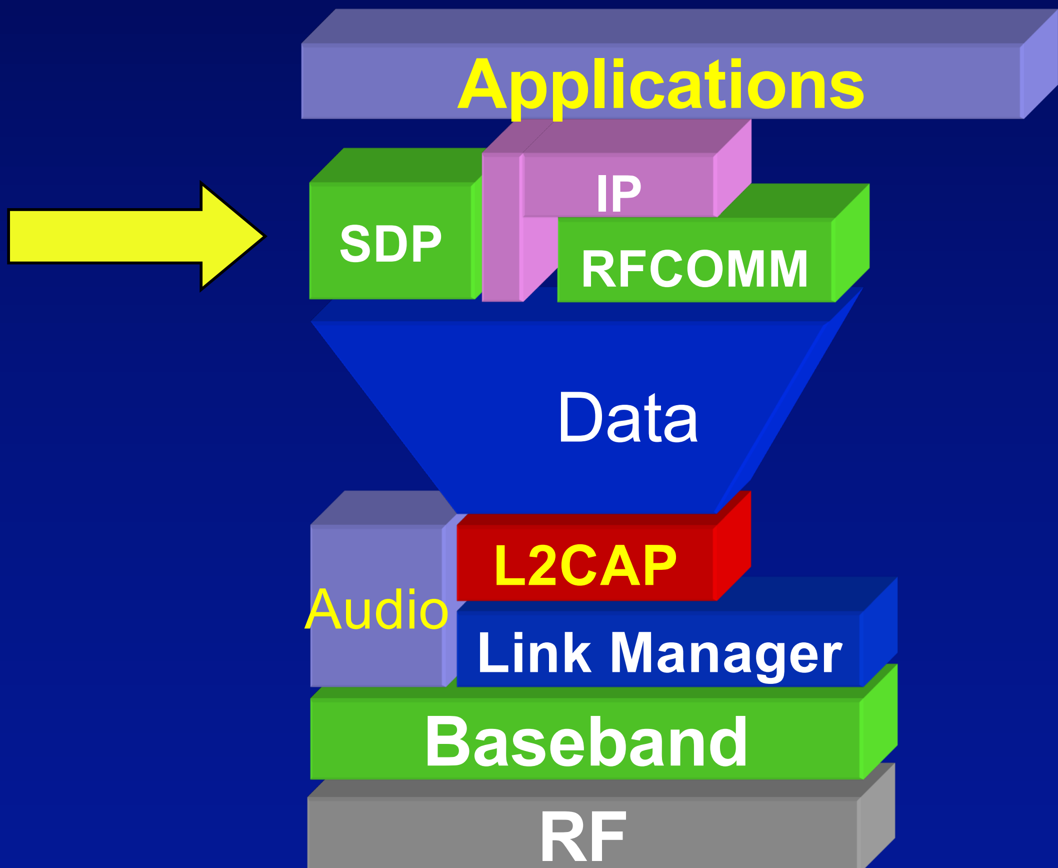
Serial Port Emulation using RFCOMM



Serial Port emulation on top of a packet oriented link

- Similar to HDLC
- For supporting legacy apps

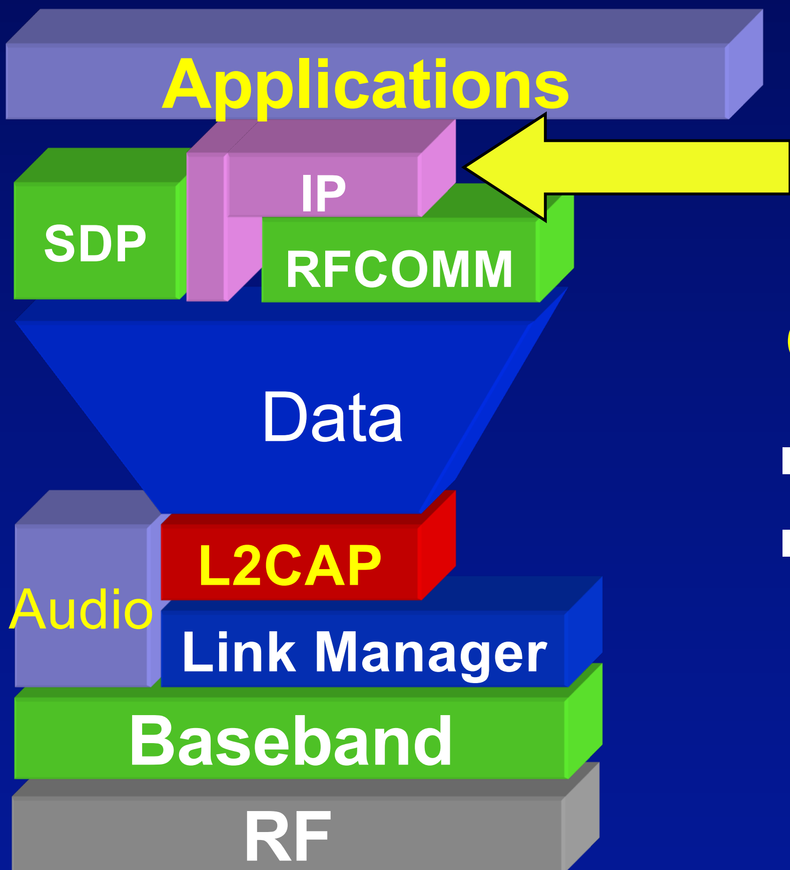
Bluetooth Service Discovery Protocol



Example usage of SDP

- Establish L2CAP connection to remote device
- Query for services
  - search for specific class of service, or
  - browse for services
- Retrieve attributes that detail how to connect to the service
- Establish a separate (non-SDP) connection to user the service

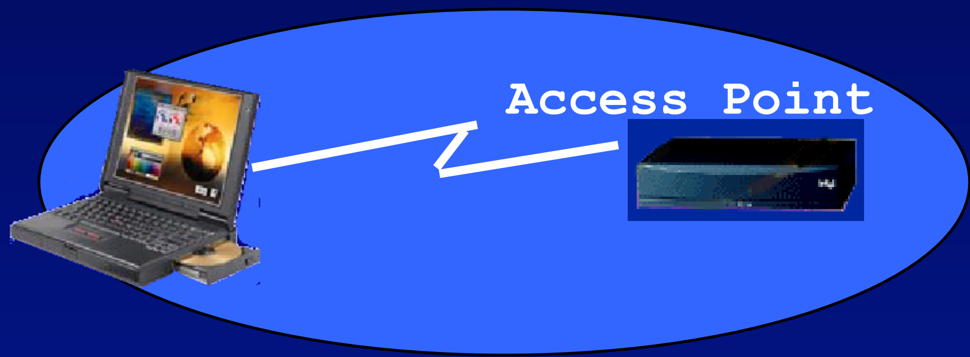
IP over Bluetooth V 1.0

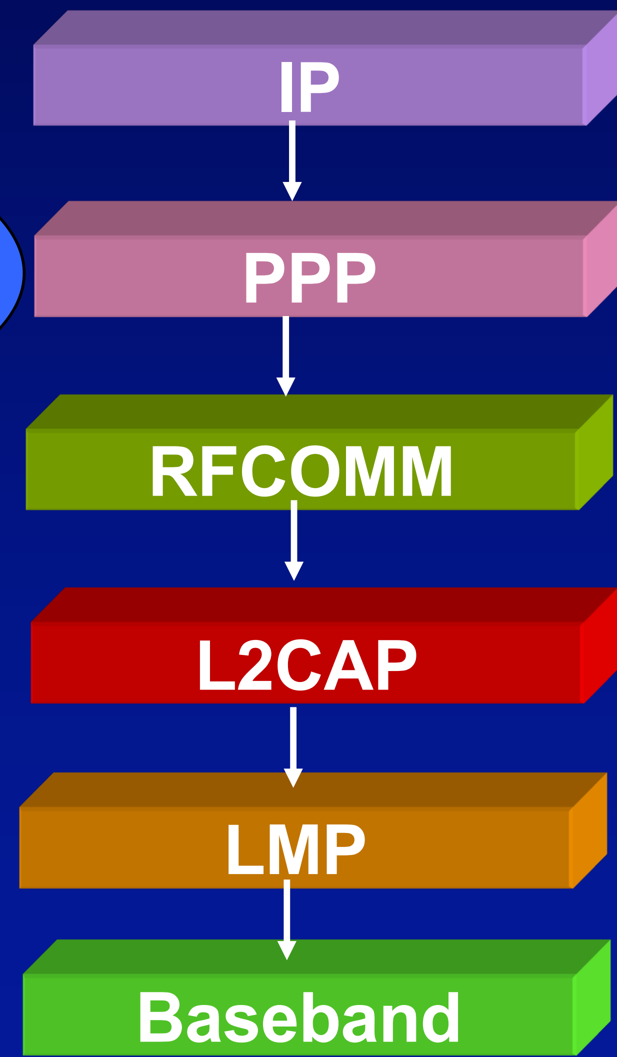


GOALS

- Internet access using cell phones
- Connect PDA devices & laptop computers to the Internet via LAN access points

LAN access point profile

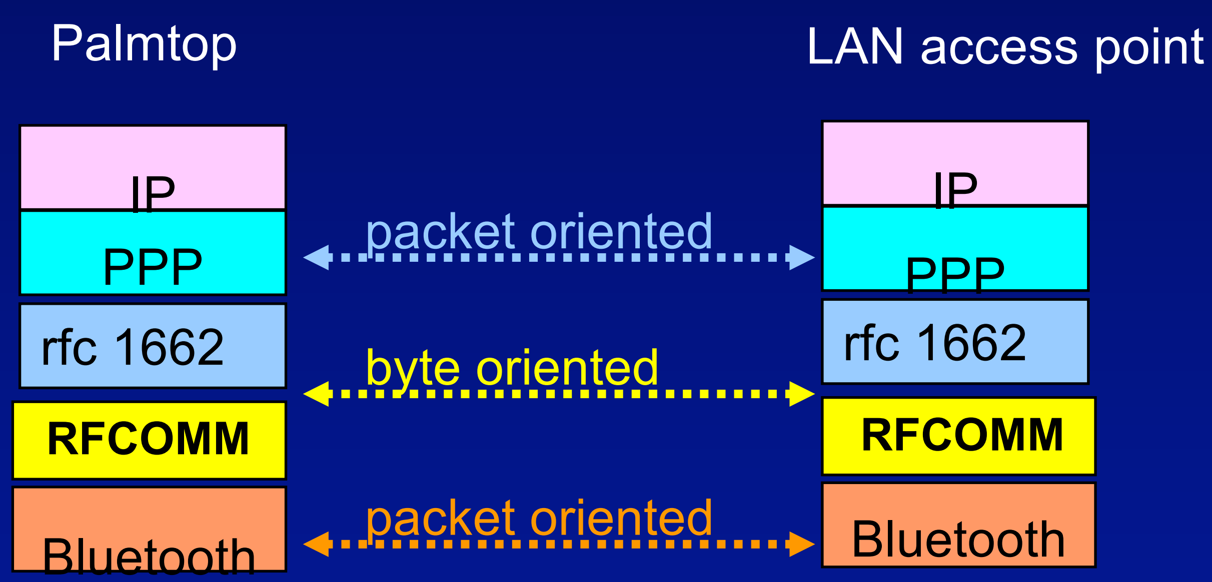




Why use PPP?

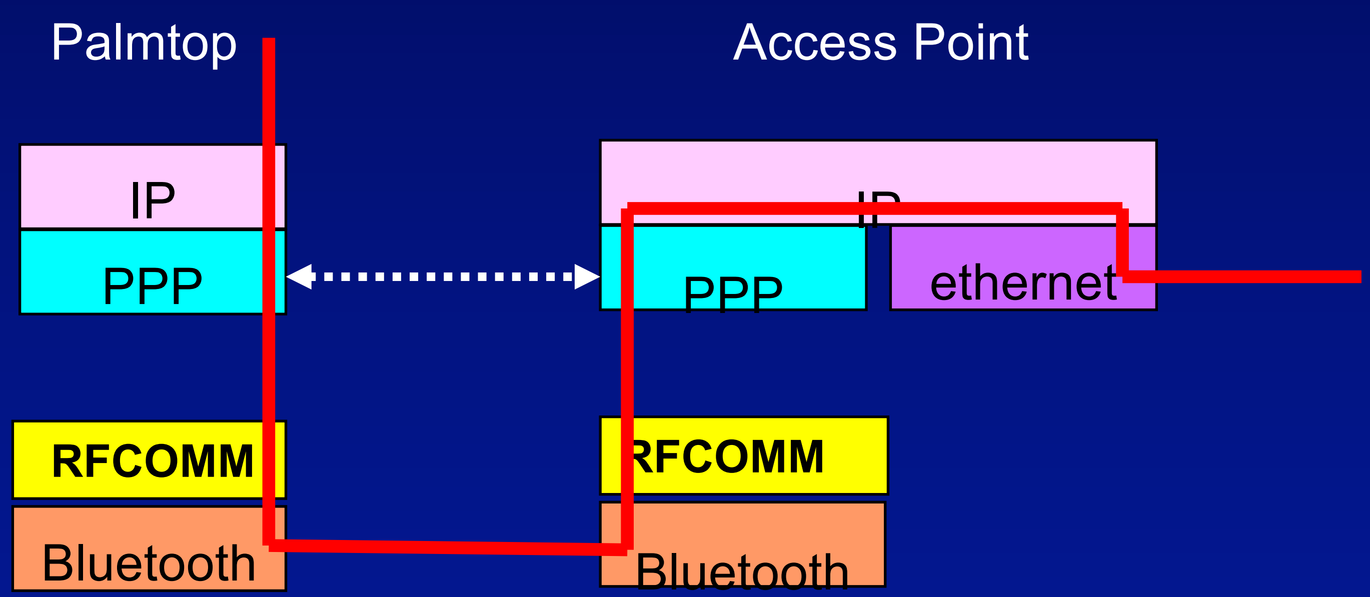
- Security
  - Authentication
  - Access control
- Efficiency
  - header and data compression
- Auto-configuration
- Lower barrier for deployment

Inefficiency of layering



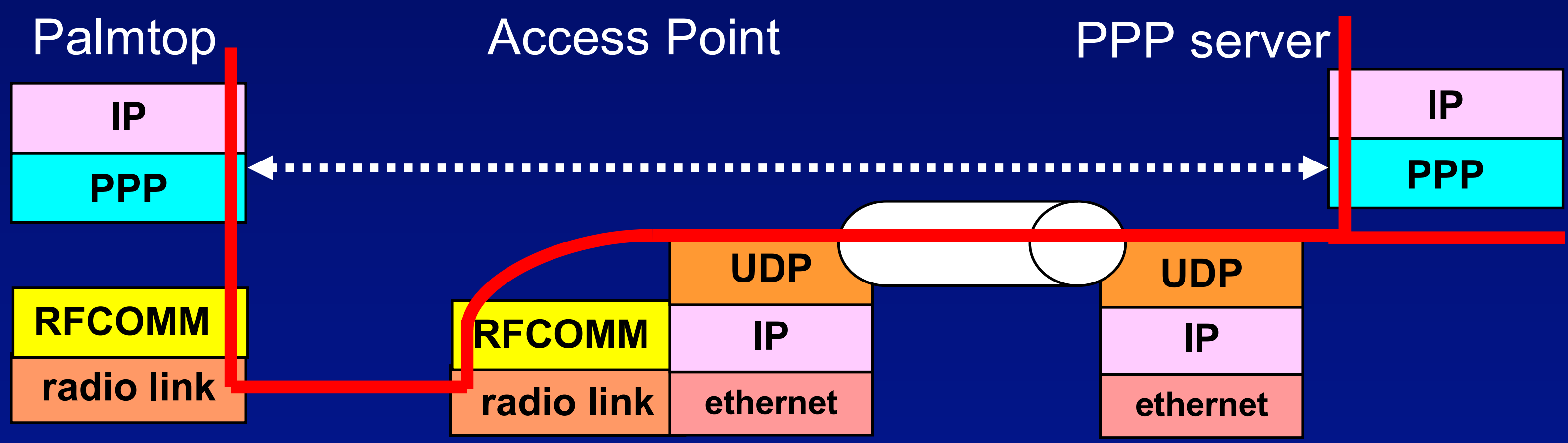
- Emulation of RS-232 over the Bluetooth radio link could be eliminated

Terminate PPP at LAN access point



- PPP server function at each access point
  - management of user name/password is an issue
  - roaming is not seamless

L2TP style tunneling



- Tunneling PPP traffic from access points to the PPP server
  - 1) centralized management of user name/password
  - 2) reduction of processing and state maintenance at each access point
  - 3) seamless roaming

IP over Bluetooth

Next steps

IP based network connectivity

IP over wireless media

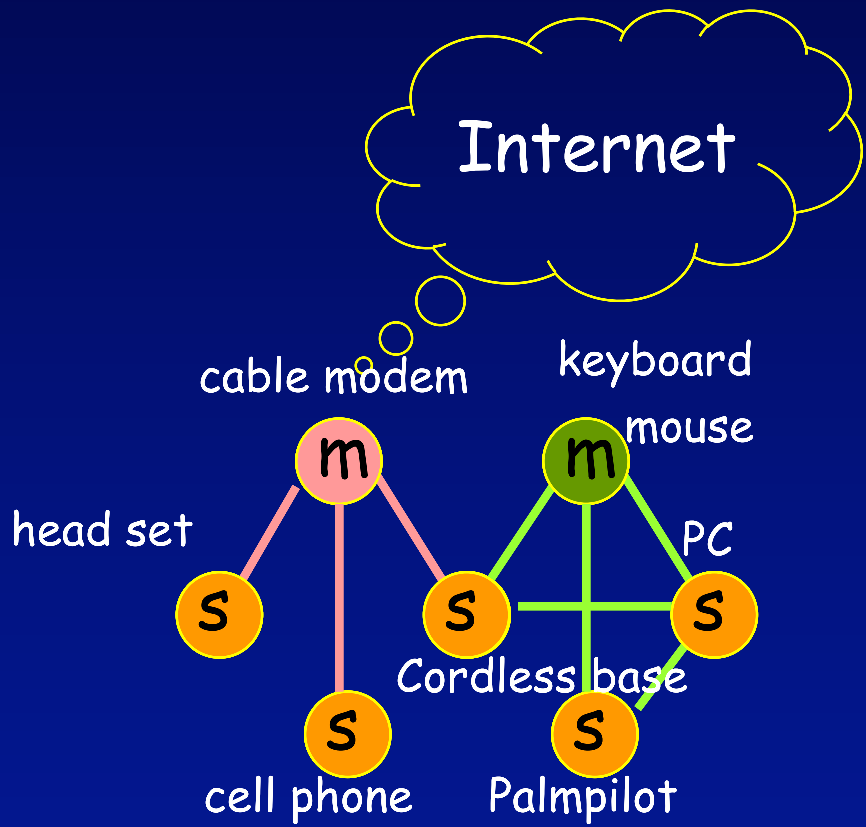
peer-to-peer connectivity

Decentralized techniques for link formulation, naming, addressing, and routing

Internet connectivity for non-PC devices

Investigation of the right design point for running IP over toasters, light switches, & fire alarms

Research challenges



Plug-n-play applications

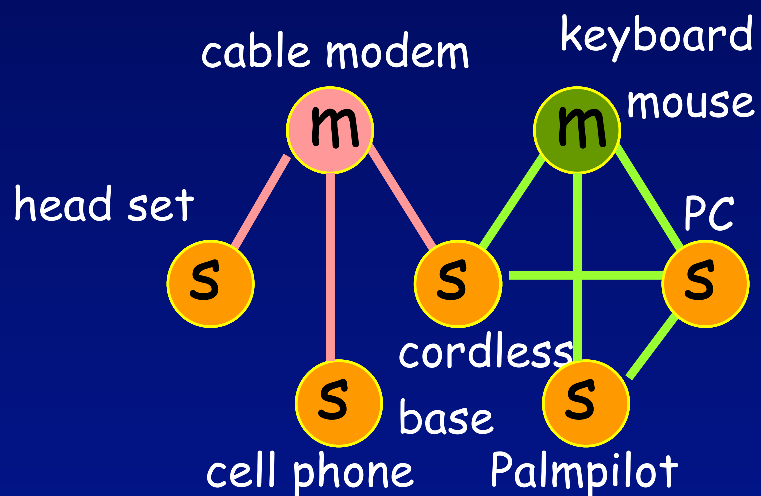
Resource Discovery

Routing over scatternets

Techniques for link formation

Will the current solutions for each layer work in this environment?

What is different in this scenario ?



Connection oriented, low-power link technology

Small, multi-hop networks

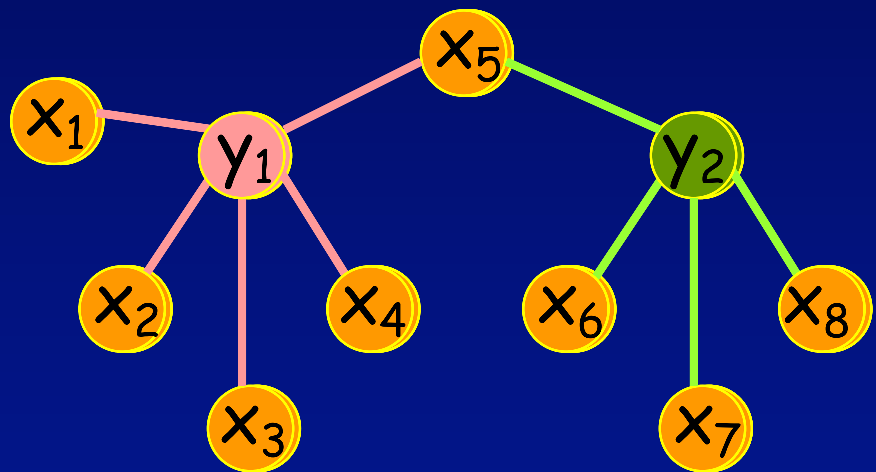
Simple devices

Isolated network

Dynamic network

Applications ---> services ----> routing ----> link creation

Link Formation



The problem does not exist
in most wired/wireless networks

Proximity ? Link

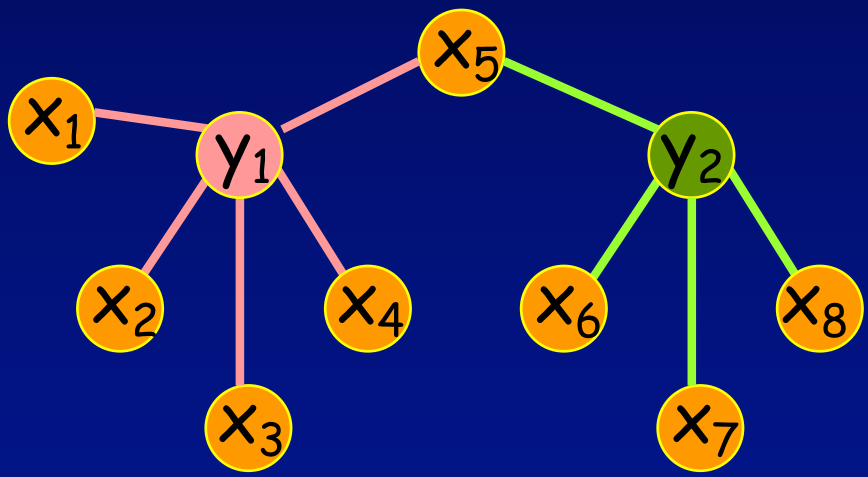
Low power modes require

careful use of broadcast

Maintaining connectivity in
absence of application traffic
seems wasteful

Hints from higher layer are needed

Routing over Scatternets



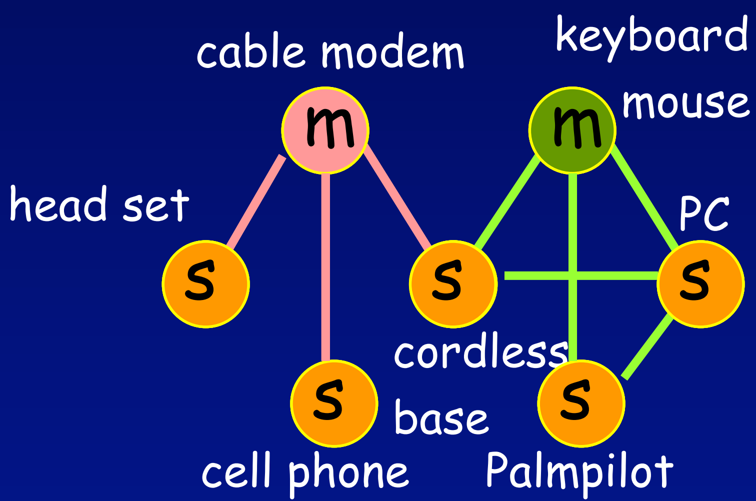
Nodes must co-operate to forward packets (MANET style protocols)

Forwarding at Layer 2 or Layer 3?

Bridging or routing ?

What interface should be exported to the above layer?
Better coupling with the service discovery layer is needed

Service discovery



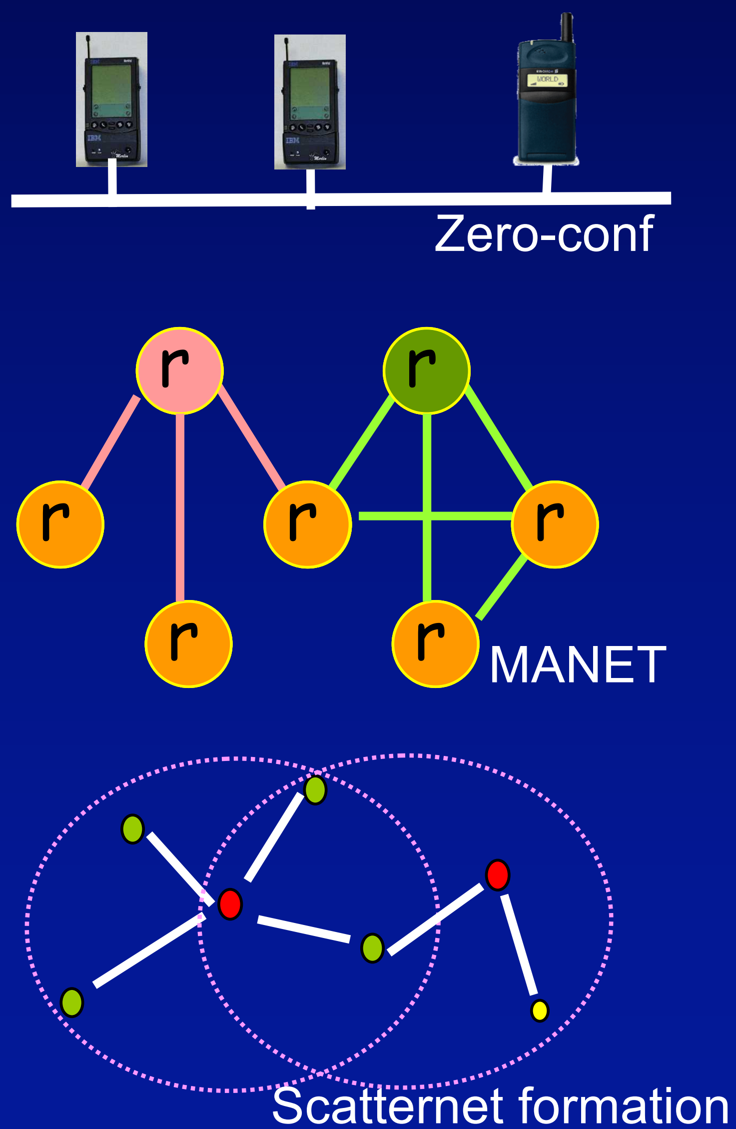
Need solutions for address allocation, name resolution, service discovery

Existing solutions in the Internet depend on infrastructure

Judicious use of Multicast/broadcast is needed

These goals are similar to what Zero-conf WG is already working on

Point to ponder



Will Zero-conf on top of MANET on top of scatternet construction algorithm solve our problem?

Layered and simple, but potential inefficiencies

Cross-layer optimizations are worth considering

Final Remarks

- Zero-conf and Bluetooth can benefit from each other
- Similarly, MANET and Bluetooth can also benefit from each other
- A new working group in IETF for IP over Bluetooth ?
- Multi-hop wireless networks will force us to re-evaluate our assumptions about network layering. Should IRTF start looking into those issues?

http://www.research.ibm.com/people/p/pravin