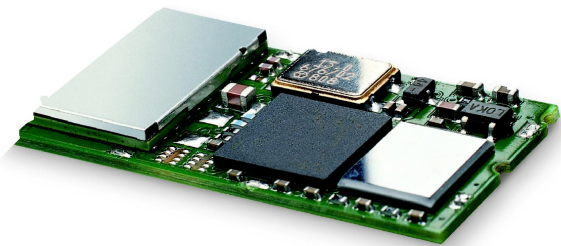
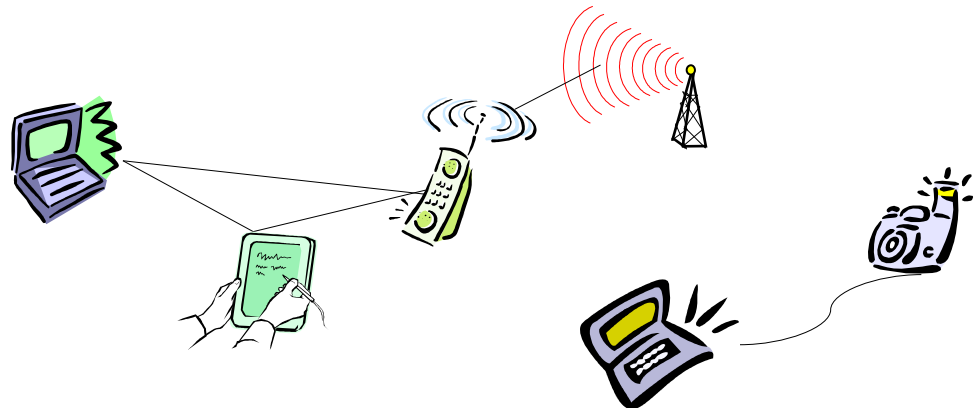


Bluetooth

- Basic idea
 - Universal radio interface for ad-hoc wireless connectivity
 - Interconnecting computer and peripherals, handheld devices, PDAs, cell phones – replacement of IrDA
 - Embedded in other devices, goal: 5€/device (already < 1€)
 - Short range (10 m), low power consumption, license-free 2.45 GHz ISM
 - Voice and data transmission, approx. 1 Mbit/s gross data rate



One of the first modules (Ericsson).

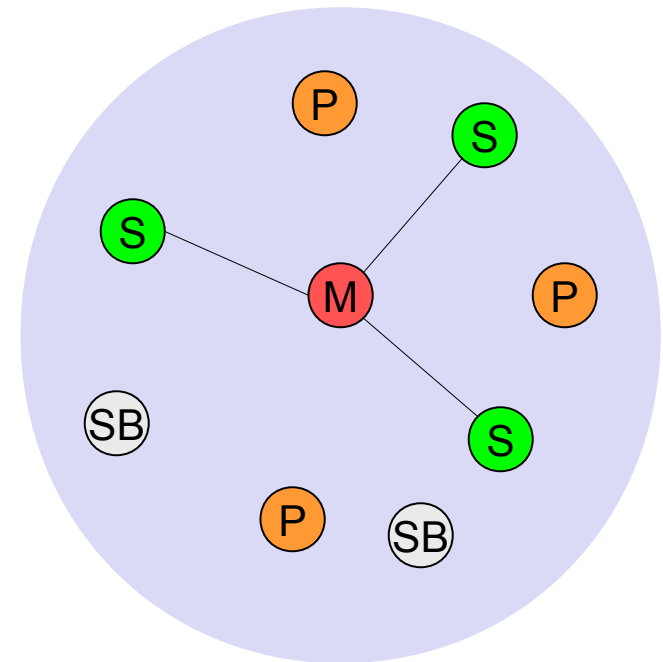


Characteristics

- 2.4 GHz ISM band, 1 MHz carrier spacing
 - Channel 0: 2402 MHz ... channel 78: 2480 MHz
 - 1-100 mW transmit power
- FHSS and TDD
 - Frequency hopping
 - Hopping sequence in a pseudo random fashion, determined by a master
 - TDD (time division duplex) – data is transmitted in one direction at a time with transmission alternating between two directions
- Voice link – SCO (Synchronous Connection Oriented)
 - FEC (forward error correction), no retransmission
 - Connection explicitly set up prior to transmitting
- Data link – ACL (Asynchronous ConnectionLess)
 - Asynchronous, packets must be acknowledged
- Topology
 - Overlapping piconets (stars) forming a scatternet

Piconet

- Collection of devices connected in an ad hoc fashion
- One unit acts as master and the others as slaves for the lifetime of the piconet
- Master determines hopping pattern, slaves have to synchronize
- Each piconet has a unique hopping pattern
- Participation in a piconet = synchronization to hopping sequence
- Each piconet has **one master** and up to 7 simultaneous slaves (> 200 could be parked)

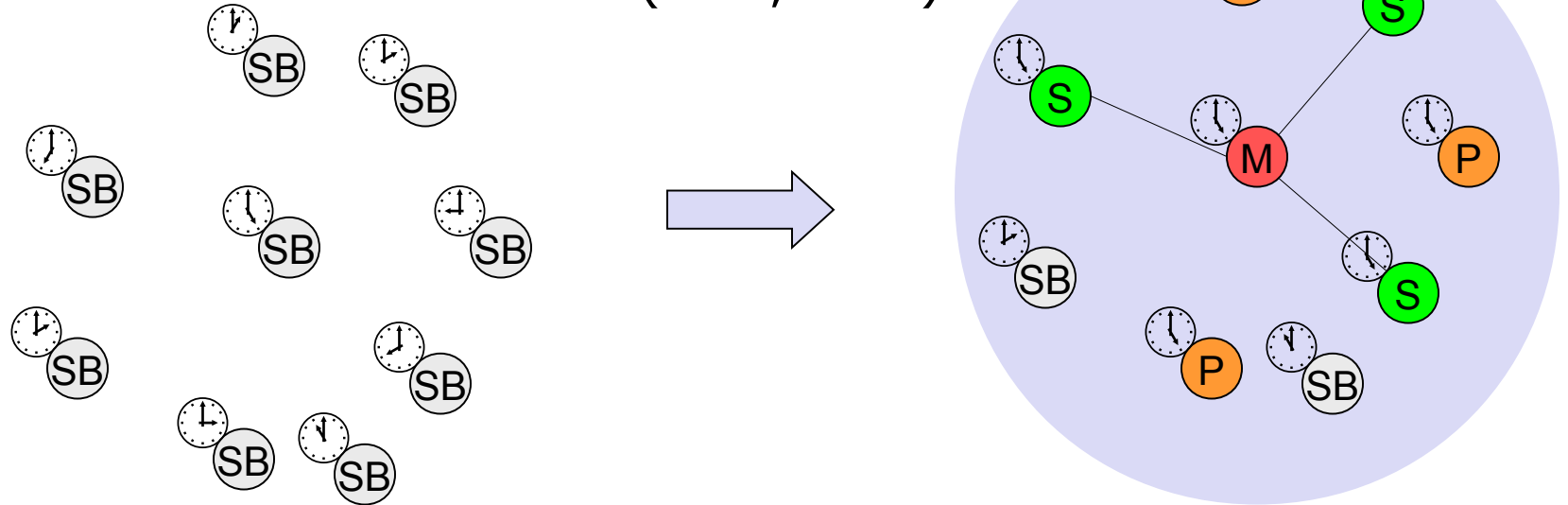


M=Master
S=Slave

P=Parked
SB=Standby

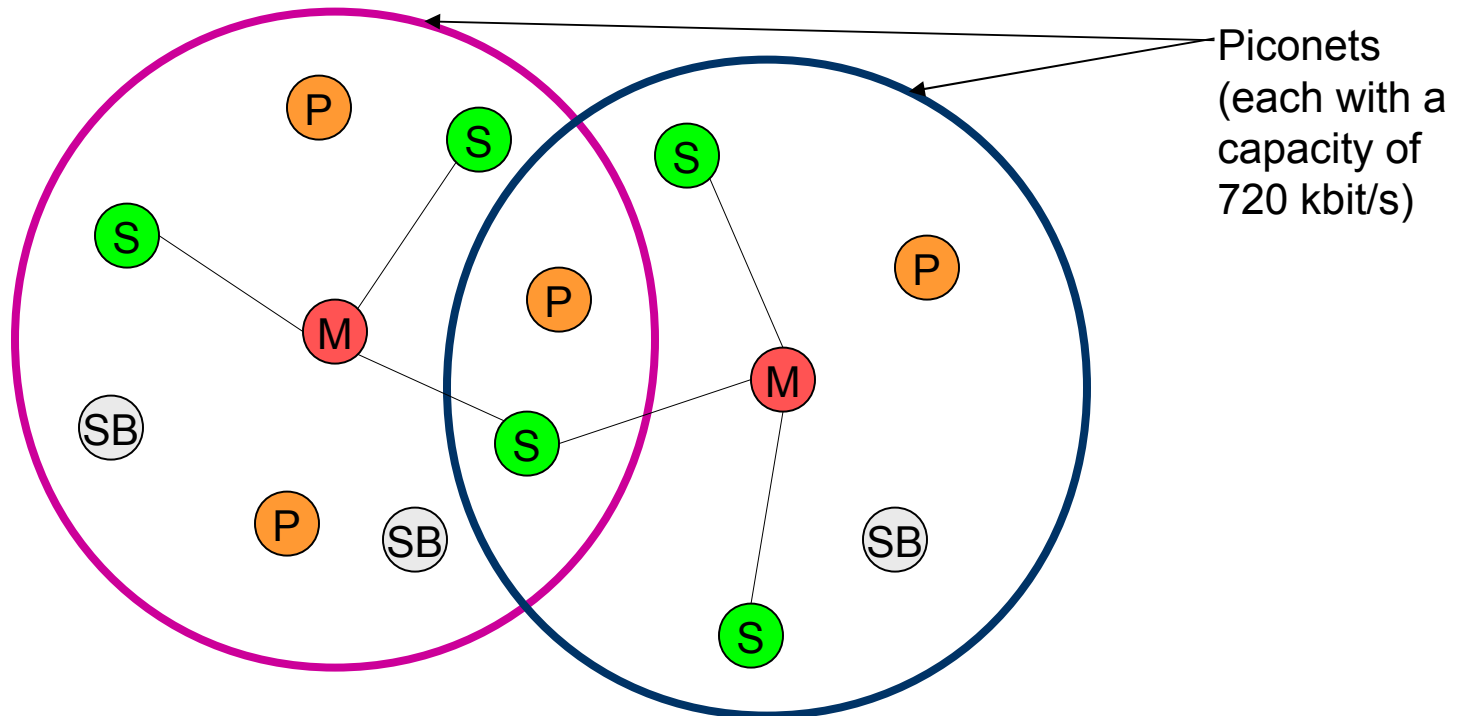
Forming a piconet

- All devices in a piconet hop together
 - Master gives slaves its clock and device ID
 - Hopping pattern: determined by device ID (48 bit, unique worldwide)
 - Phase in hopping pattern determined by clock
- Addressing
 - Active Member Address (AMA, 3 bit)
 - Parked Member Address (PMA, 8 bit)

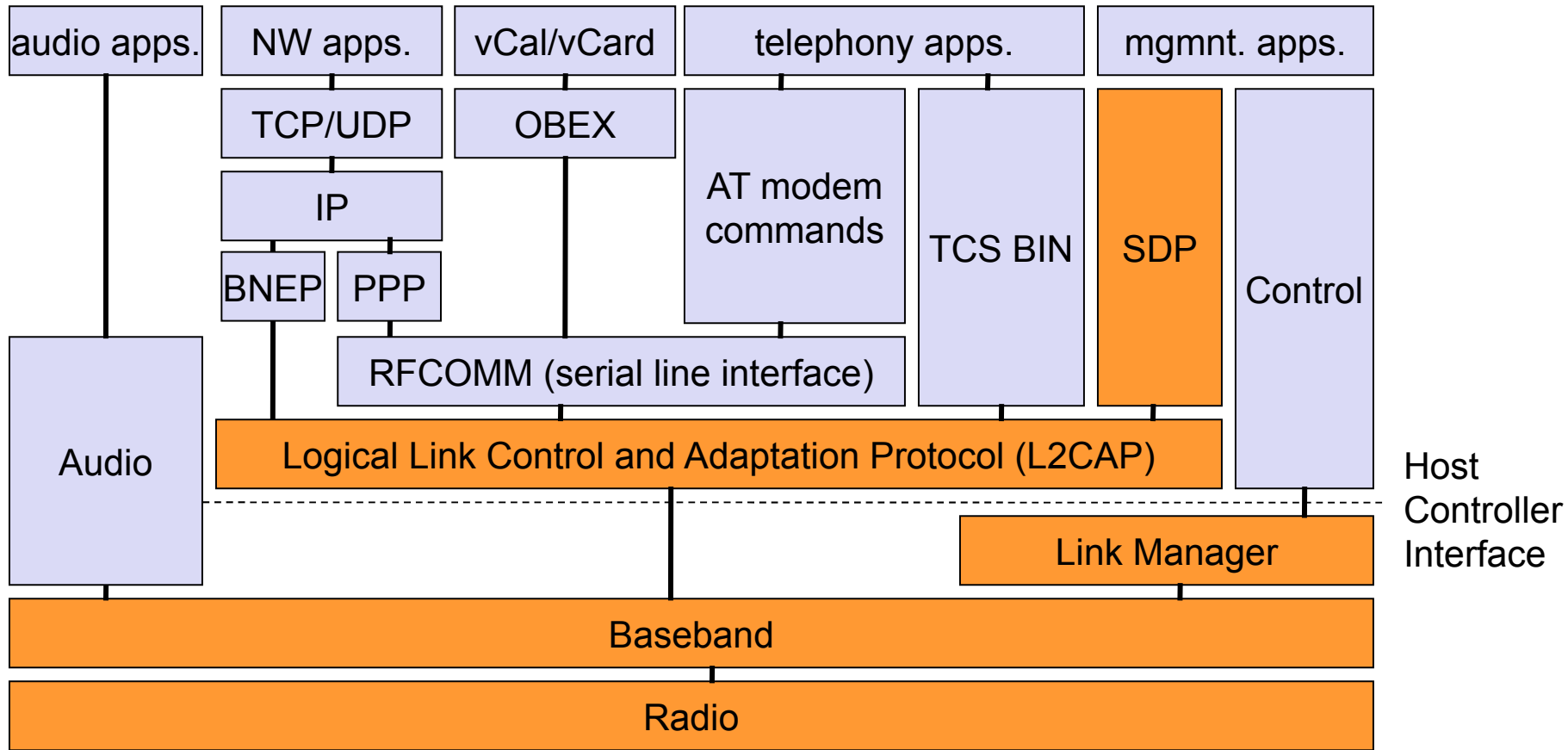


Scatternet

- Linking of multiple co-located piconets through the sharing of common master or slave devices
 - Devices can be slave in one piconet and master of another
- Communication between piconets
 - Devices jumping back and forth between the piconets



Bluetooth protocol stack



AT: attention sequence
 OBEX: object exchange
 TCS BIN: telephony control protocol specification – binary
 BNEP: Bluetooth network encapsulation protocol

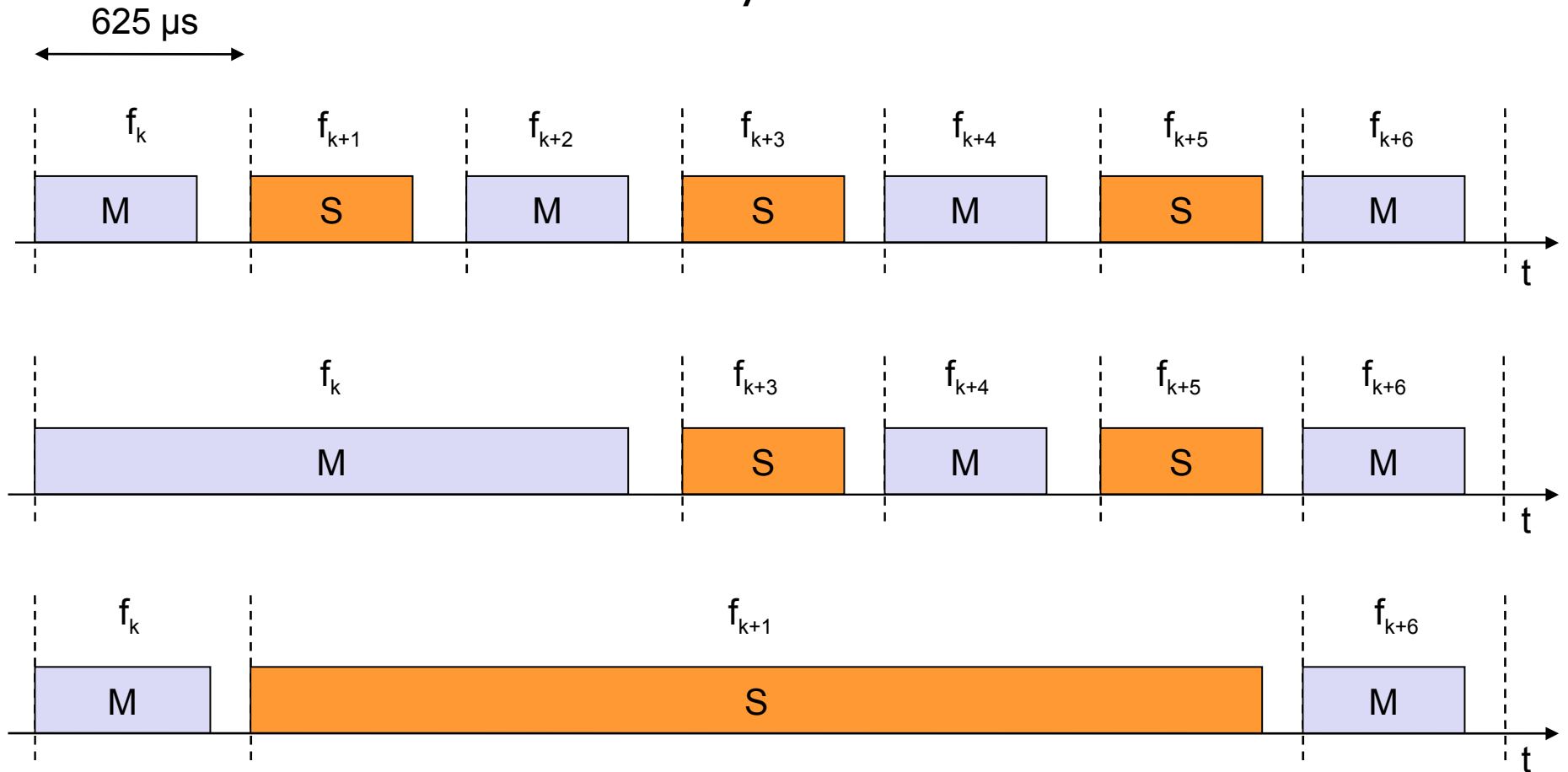
SDP: service discovery protocol
 RFCOMM: radio frequency comm.

Radio Layer

- Rather a short document
- Only defines the carrier frequencies and output power
- Bluetooth is targeted to low power devices
- And yes, for interoperable licensed channels
 - So 2.4 GHz
- Uses FHSS for transmission
- The time between hops is 625 microseconds
- Bluetooth power is available in three classes
 - Power class 1 (1~100mW)
 - Power class 2 (0.25~2.5mW, typically 1mW)
 - Power class 3 (max 1mW)

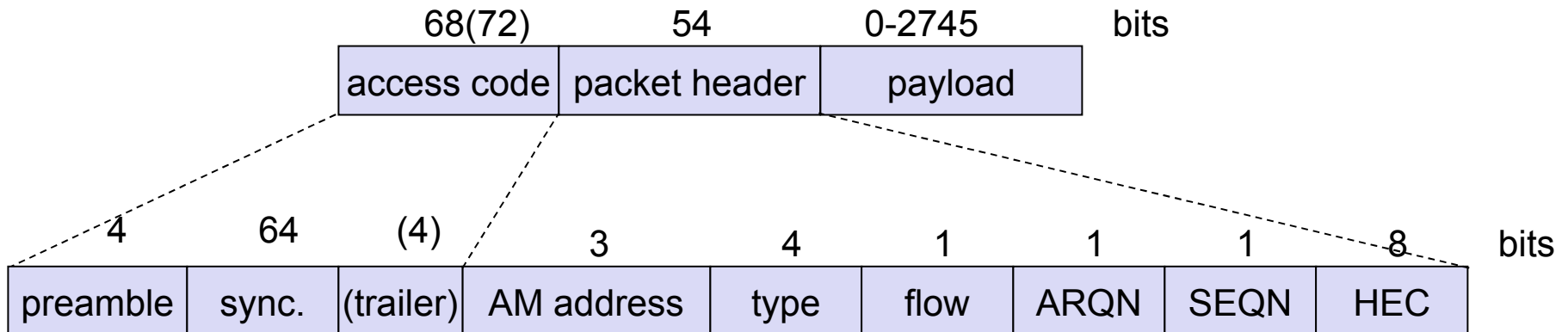
Frequency selection during data transmission

multislot only for ACL transmissions



Baseband

- Piconet/channel definition
- Low-level packet definition
 - Access code
 - Channel, device access, trailer (0101 if rightmost bit is 1, 0 otherwise)
 - Packet header
 - 1/3-FEC, active member address (broadcast + 7 slaves), link type, alternating bit ARQ/SEQ, checksum



Packet Header Framing

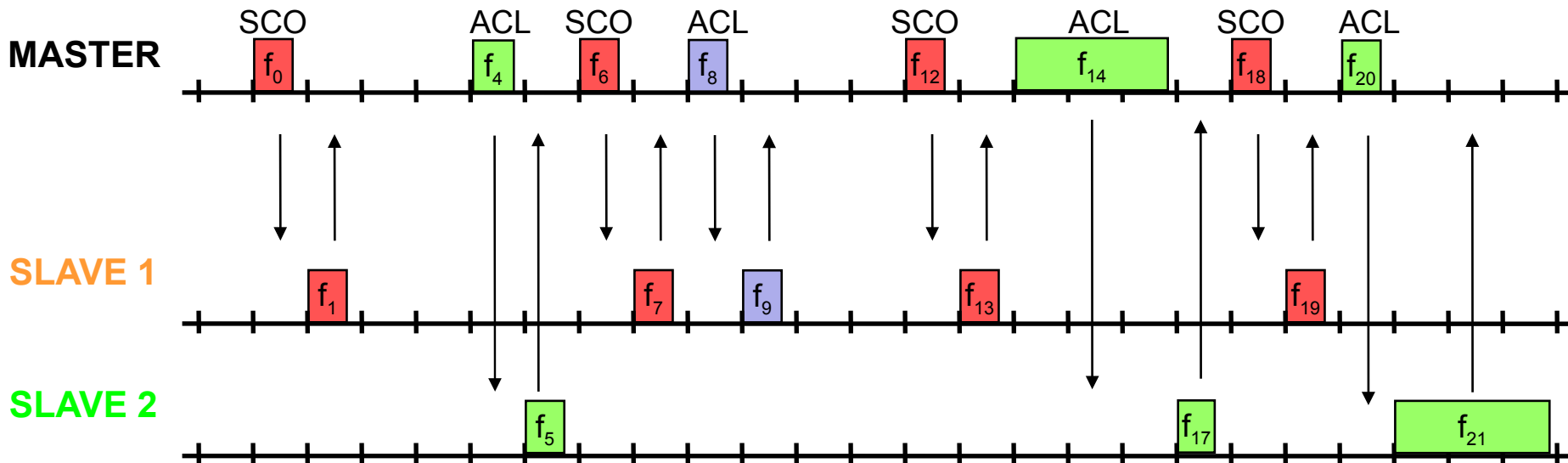
- “AM address” is a 3 bit active member address
- Master to slave → the address is the receiver address
- Slave to master → the address is the sender address
- 0000 value → broadcast
- Type → type of packet (e.g. control packets)
- Flow (1 halt ACL transmission, 0 resume)
- ARQN (1 – ACK, 0 NACK) for ACL transmissions
- SEQN (Sequential number) – packets are labeled between 0/1
- HEC – header error control

Bluetooth link types

- Synchronous connection oriented link (SCO)
 - Similar to phone calls
 - Point to point connections
 - A master can support up to three simultaneous links to the same slave
 - Data and voice
 - No retransmissions
 - Time critical applications
 - Single slot packets
- Asynchronous connectionless link (ACL)
 - Multi point and broadcast transfer mechanisms
 - Retransmission if packet is lost
 - ACK and NACK
 - 1, 3, 5 slot packets allowed

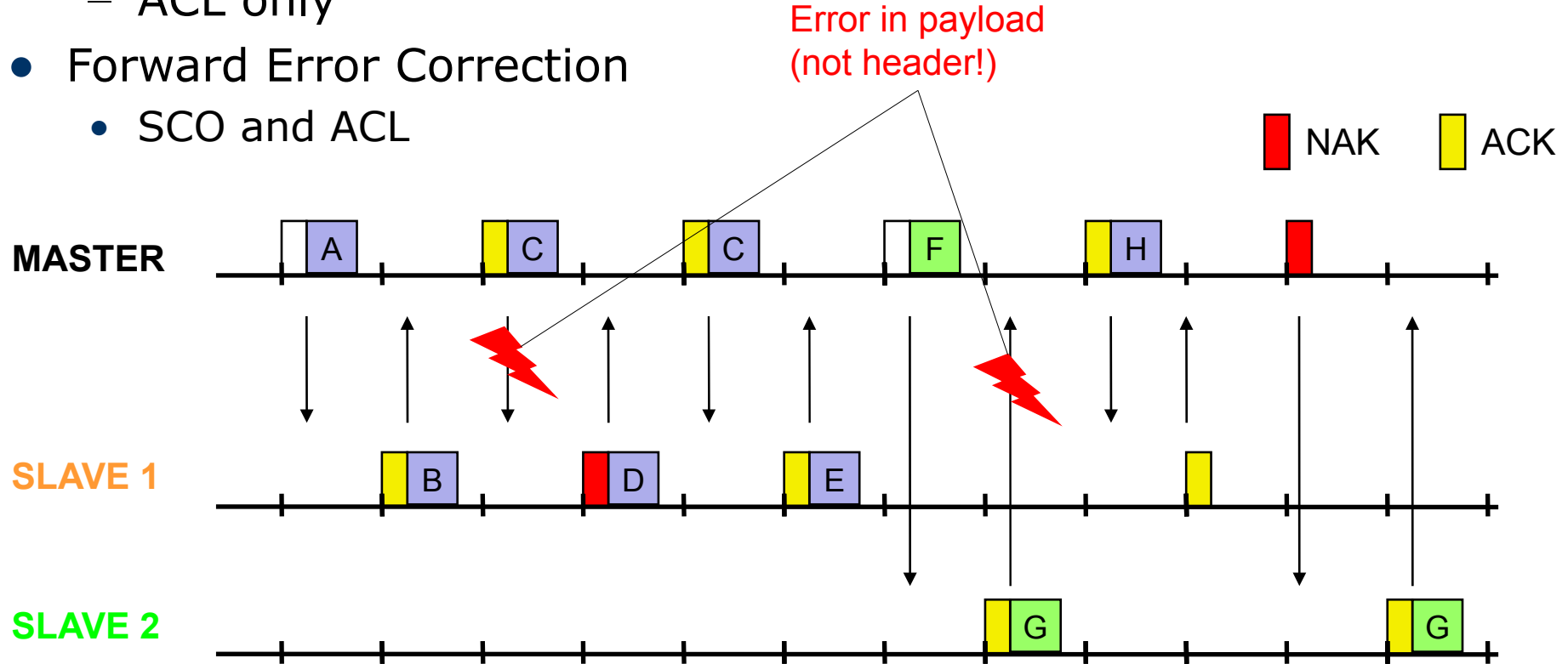
Baseband link types

- Polling-based TDD (time division duplex) packet transmission
 - 625 μ s slots, master polls slaves
- SCO (Synchronous Connection Oriented) – Voice
 - Periodic single slot packet assignment, 64 kbit/s full-duplex, point-to-point
- ACL (Asynchronous ConnectionLess) – Data
 - Variable packet size (1, 3, 5 slots), asymmetric bandwidth, point-to-multipoint



Robustness

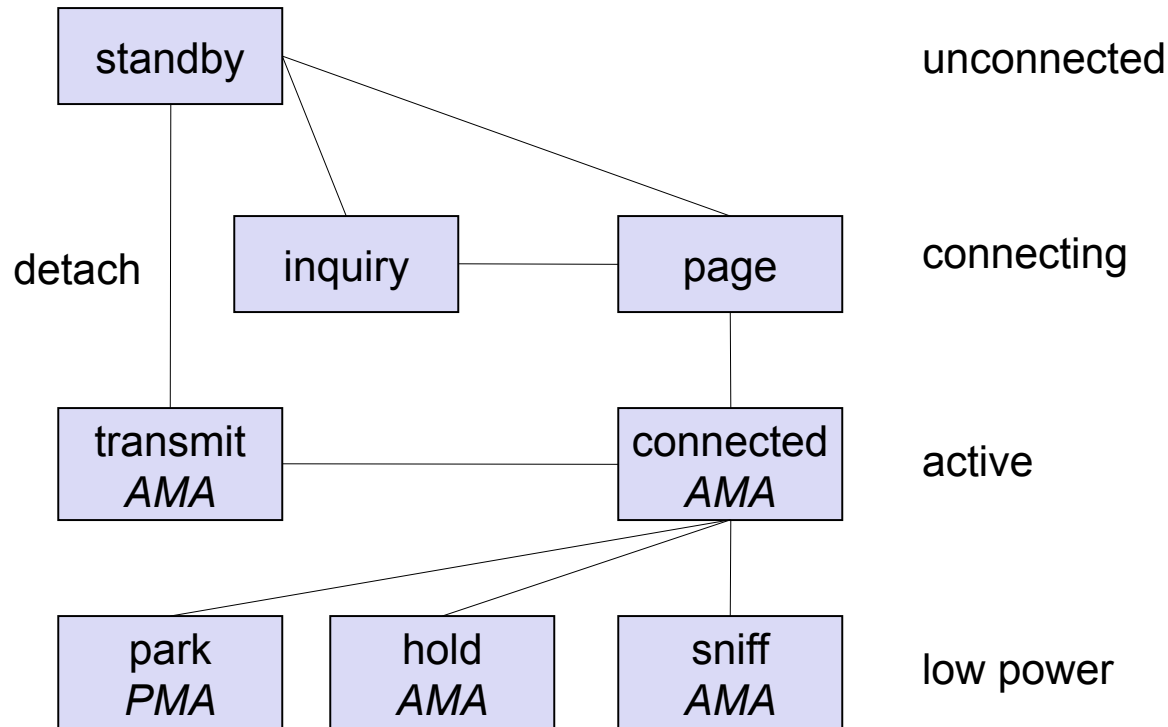
- Slow frequency hopping with hopping patterns determined by a master
 - Protection from interference on certain frequencies
- Retransmission
 - ACL only
- Forward Error Correction
 - SCO and ACL



Link Manager Roles

- Authentication – sets the encryption mode (e.g. no encryption), key size, etc.
- Synchronization – clock offset is updated
- Capability negotiation – Not all features are supported, so devices need to agree the usage of e.g. multi-slot packets, etc.
- Quality of service negotiation – e.g. limit number of slots for slave answers, latency control, FEC protection or no protection, etc.
- Power control – Decrease transmissions according to battery power
- Link supervision – set up new SCO links, destroy
- State transition – changing from unconnected, connected, active and low power modes

Baseband states of a Bluetooth device



Standby: do nothing

Inquire: search for other devices

Page: connect to a specific device

Connected: participate in a piconet

Park: release AMA, get PMA

Sniff: listen periodically, not each slot

Hold: stop ACL, SCO still possible, possibly participate in another piconet

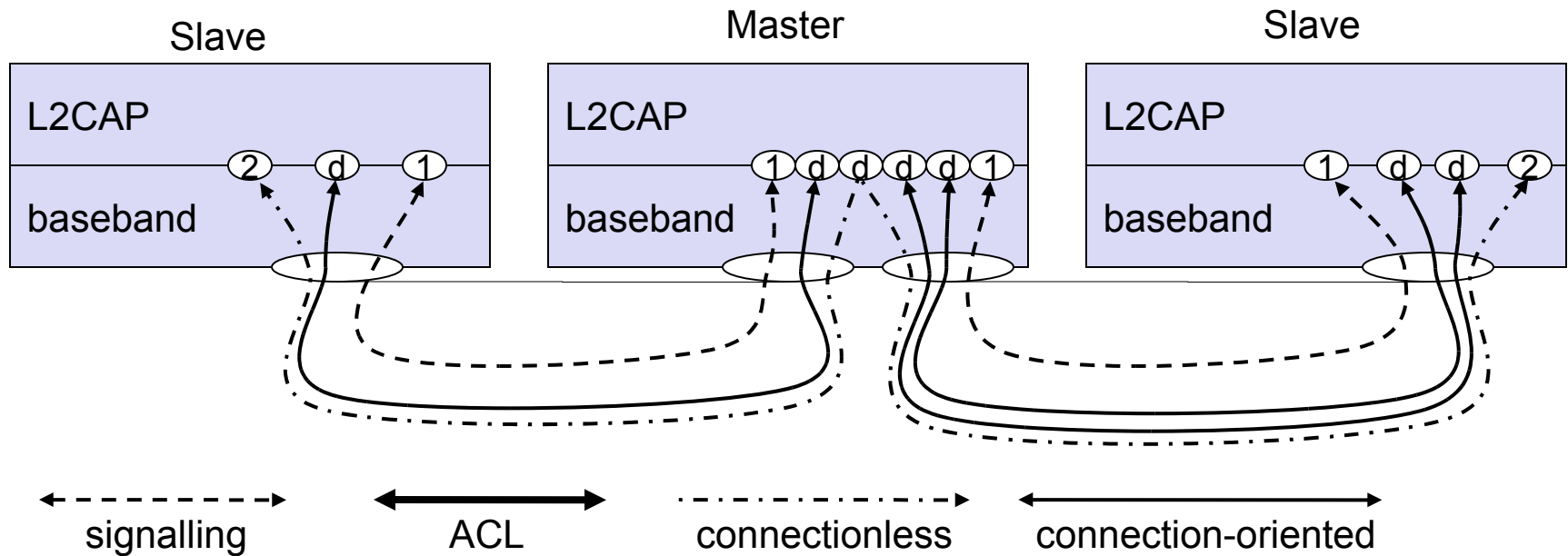
L2CAP - Logical Link Control and Adaptation Protocol



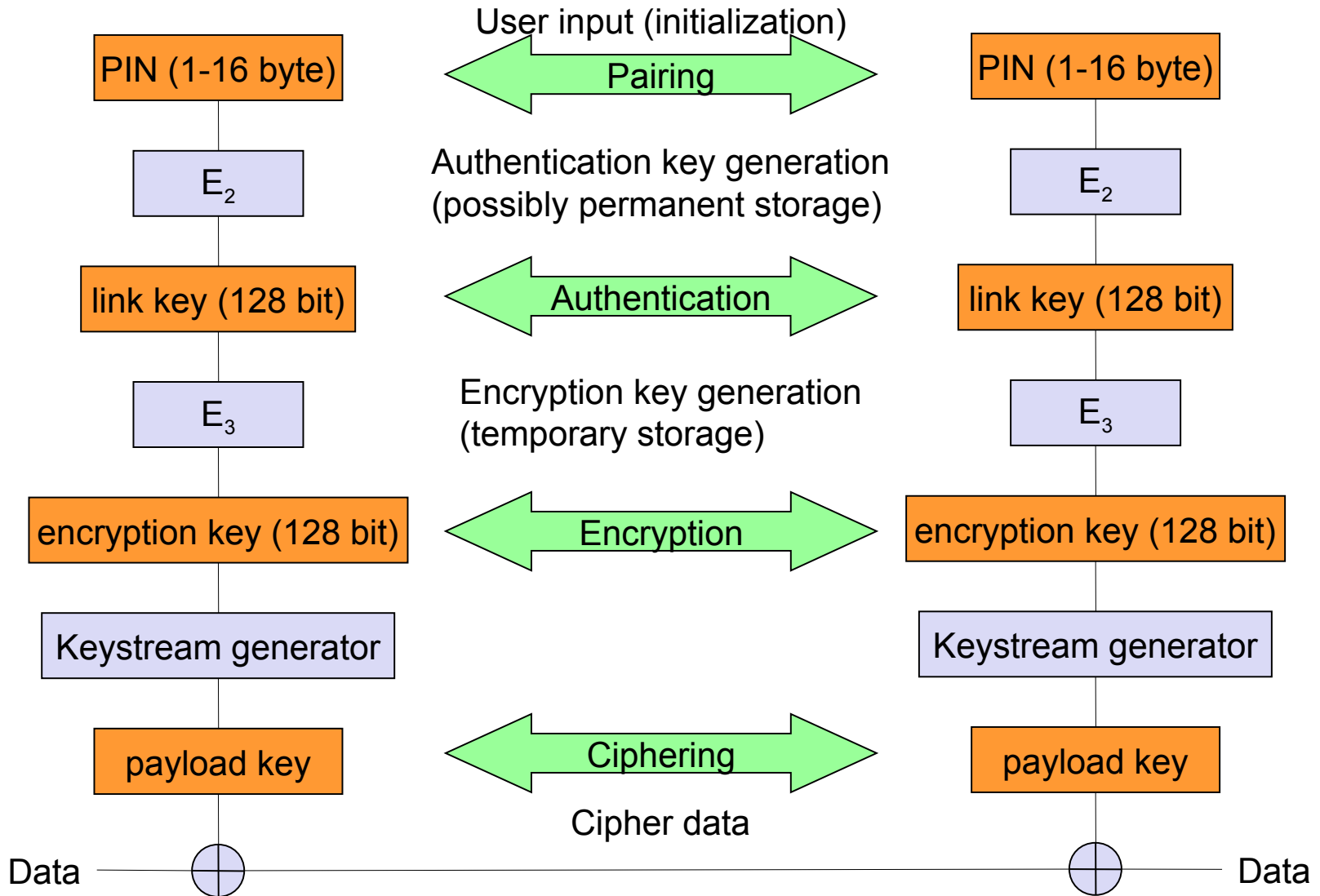
- Simple data link protocol on top of baseband
- Connection oriented, connectionless, and signaling channels
 - Employed to send messages between L2CAP entities
- Segmentation & reassembly
- QoS flow specification per channel
 - Specifies delay, bandwidth, etc.
- Group abstraction
 - Create/close group, add/remove member

L2CAP logical channels

- Why are connectionless links unidirectional?



Security



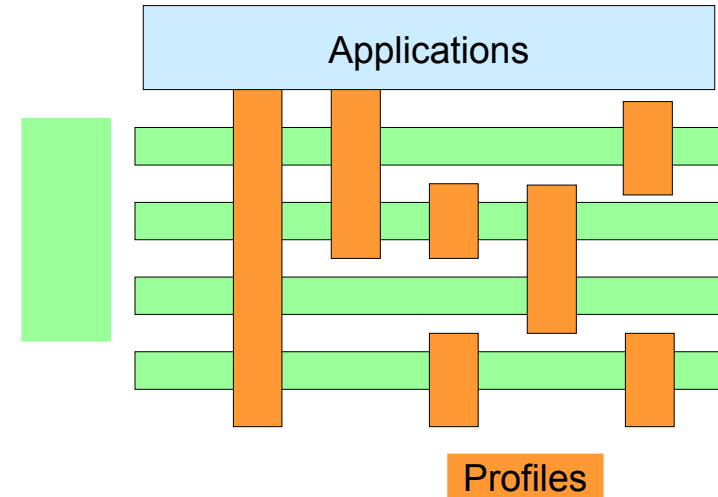
SDP – Service Discovery Protocol

- Inquiry/response protocol for discovering services
 - Searching for and browsing services in radio proximity
 - Adapted to the highly dynamic environment
 - Can be complemented by others like SLP, Jini,
 - Defines discovery only, not the usage of services
 - Caching of discovered services
 - Gradual discovery

Profiles

- Represent default solutions for a certain usage model
 - Vertical slice through the protocol stack
 - Basis for interoperability
- Service Discovery Application Profile
- Cordless Telephony Profile
- Serial Port Profile
- Headset Profile
- Dial-up Networking Profile
- Fax Profile
- LAN Access Profile
- Generic Object Exchange Profile
- Object Push Profile
- File Transfer Profile
- Synchronization Profile

Protocol Stack



- Additional Profiles**
- PAN
 - Audio Video Remote Control
 - Basic Printing
 - Basic Imaging
 - Extended Service Discovery

Finalizando o Bluetooth

- Leiam o capítulo 7