
# Short-range radio communications with BLUETOOTH™

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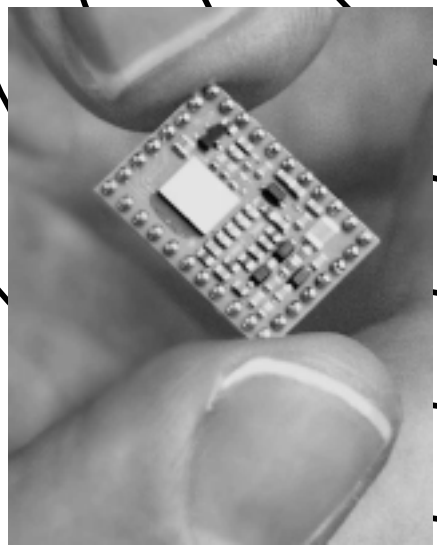
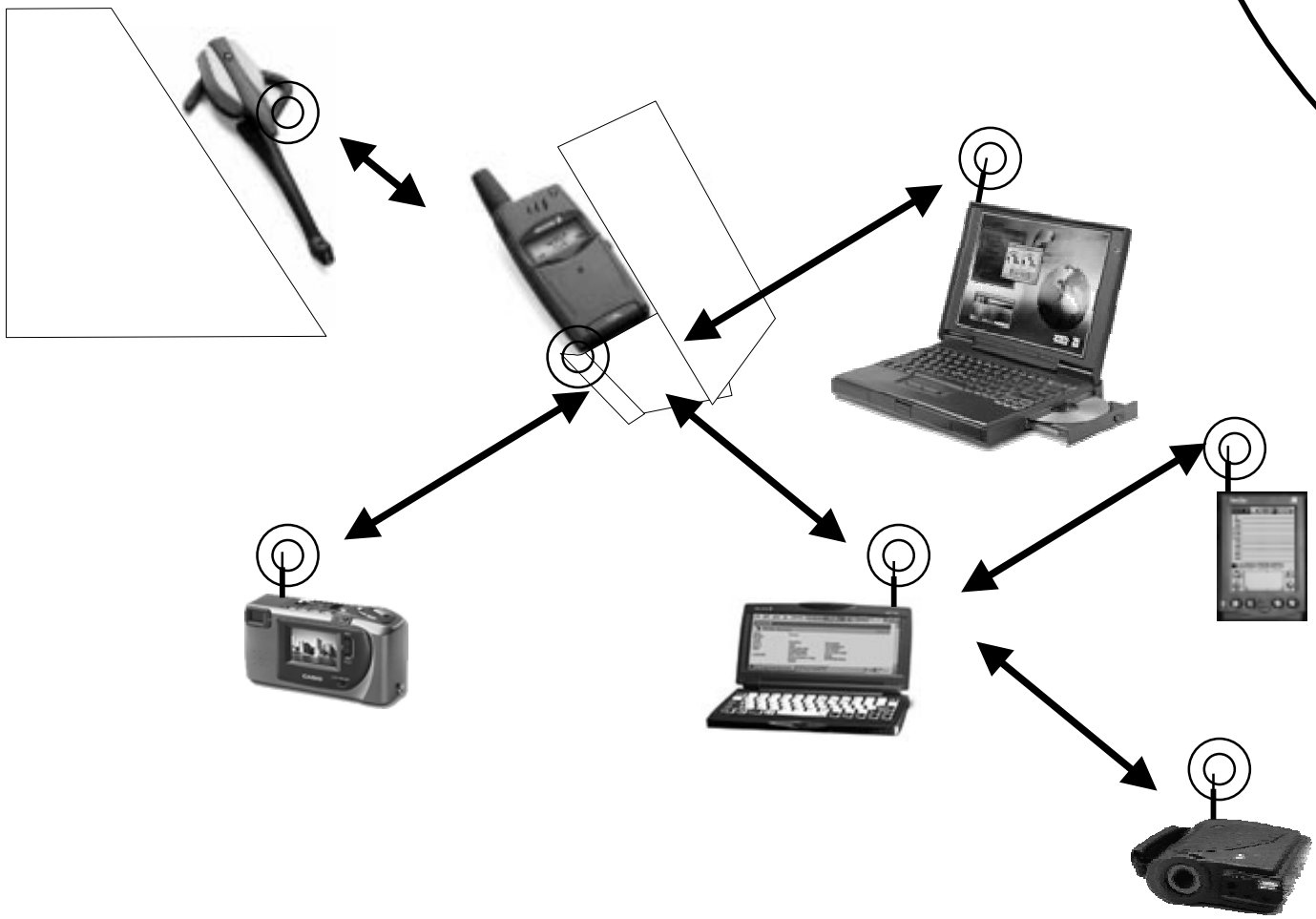
University of Seoul

Bluetooth™

ERICSSON

# EMBEDDED CONNECTIVITY

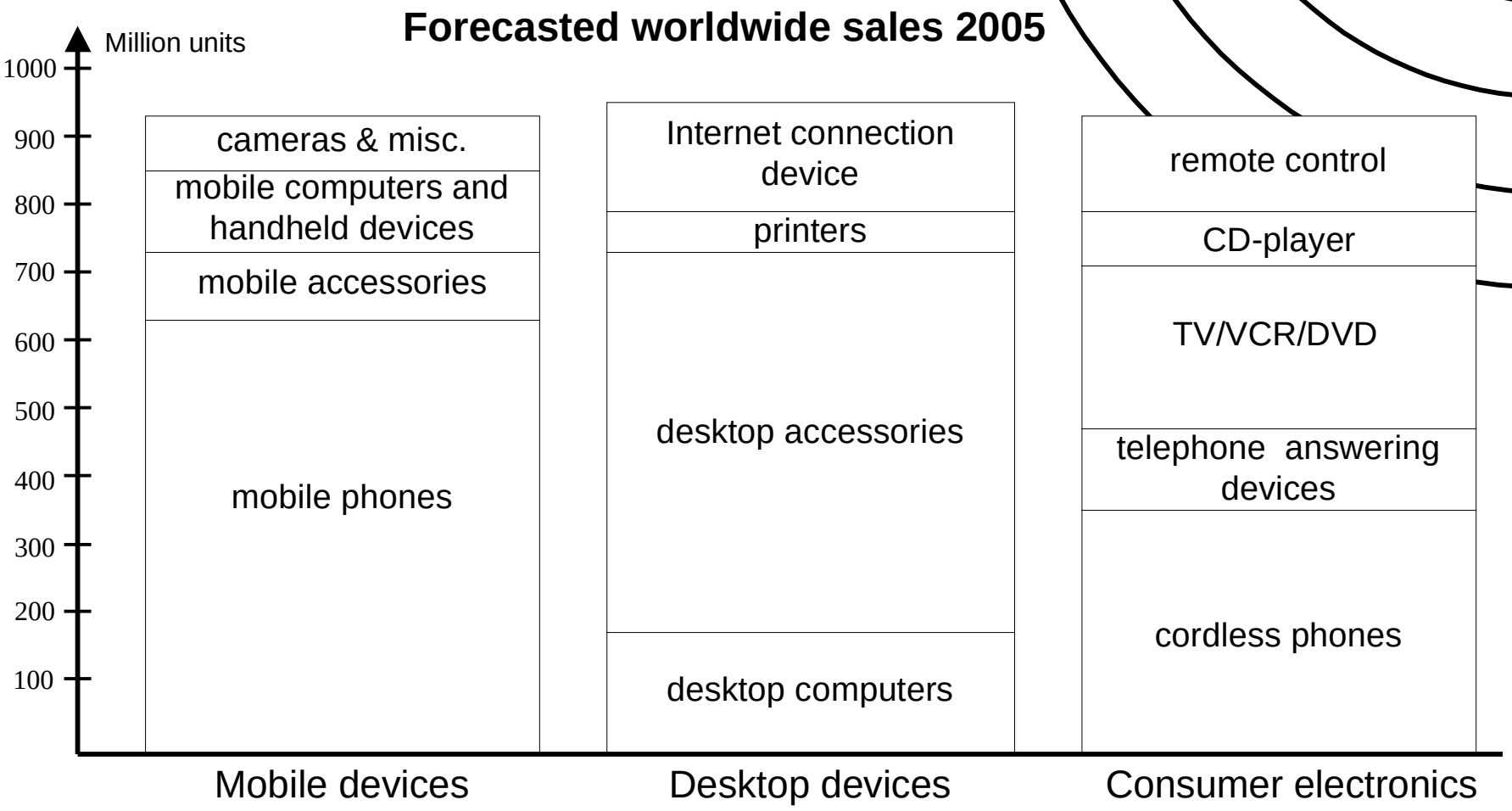




# BACKGROUND SYNCHRONIZATION

- Hidden computing
- Hidden communications

# THE POTENTIAL




Source: IDC, Strategy Analytics, Ericsson, Silver Institute.

# THE NAME

## Harald Bluetooth II

### King of Denmark 940-981

**This is one of two Runic stones erected in his capitol city of Jelling**

**• The stone's inscription ("runes") say:**

- Harald christianized the Danes
- Harald made peace
- Harald thinks notebooks and cellular phones should be seamlessly connected

# OUTLINE

- **Core design issues**
- **Application areas**
- **Protocol stack**
  - radio & baseband
  - link manager
  - L2CAP & HCI
  - software stack
- **Profiles**
- **Implementation issues**

# CORE DESIGN ISSUES

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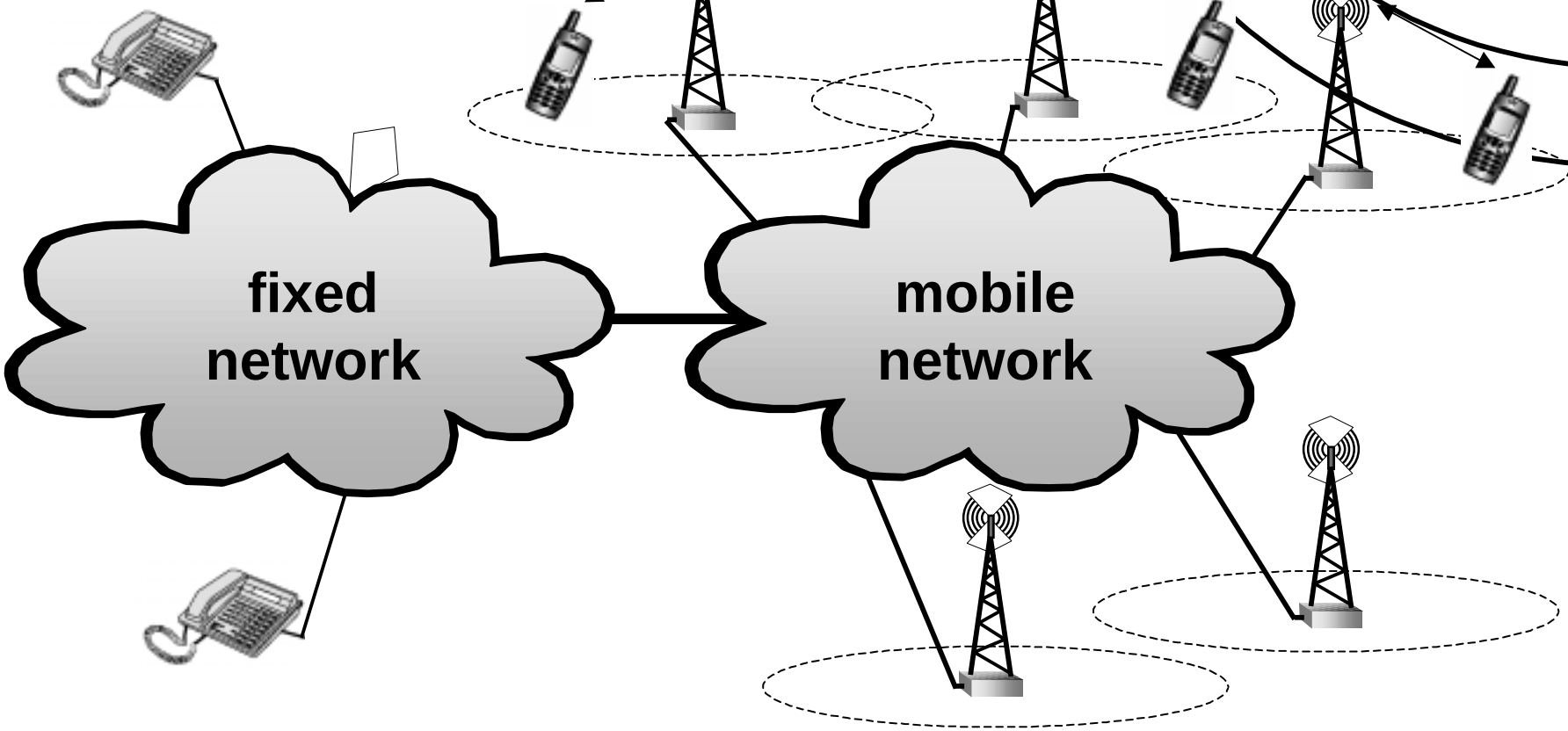
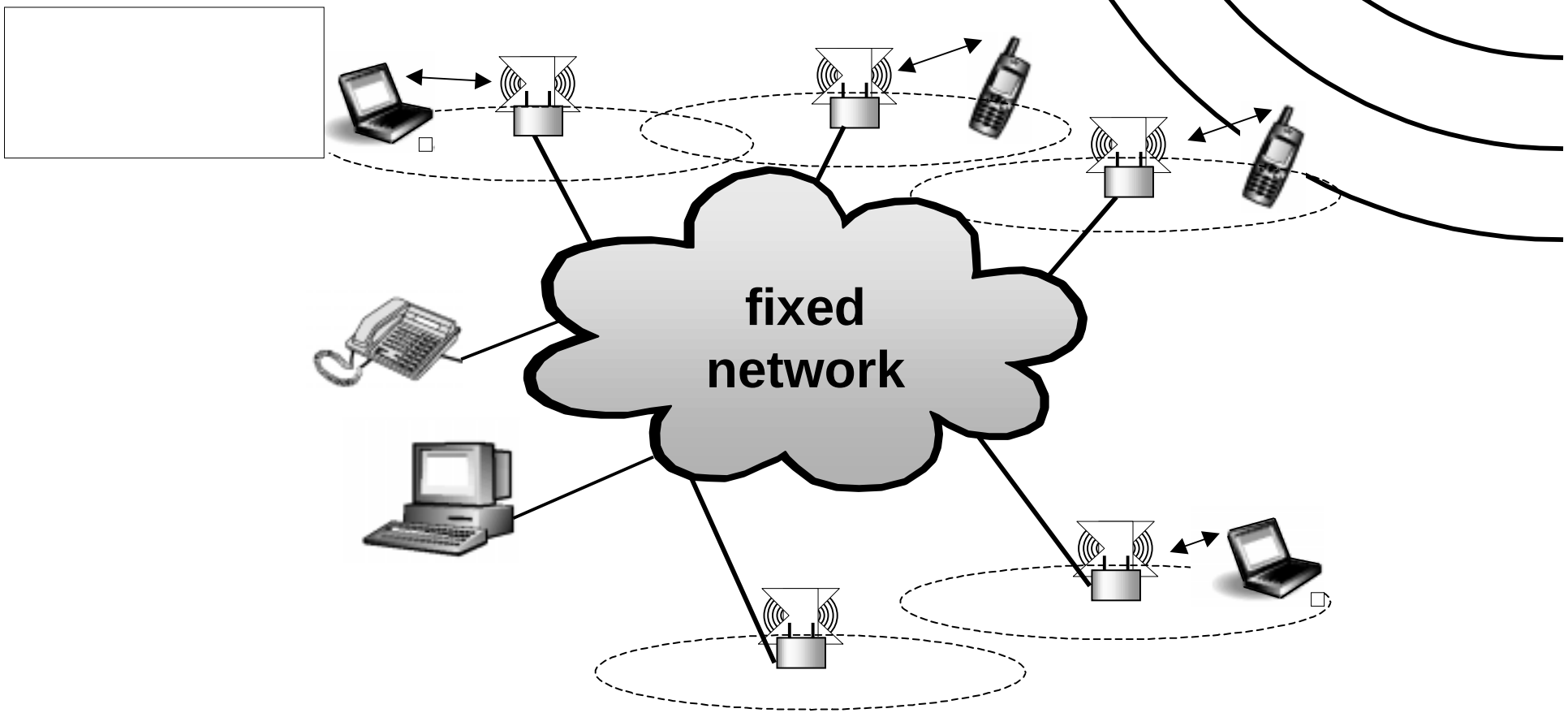
- Ad-hoc connectivity
- Radio spectrum
- Low-cost implementation

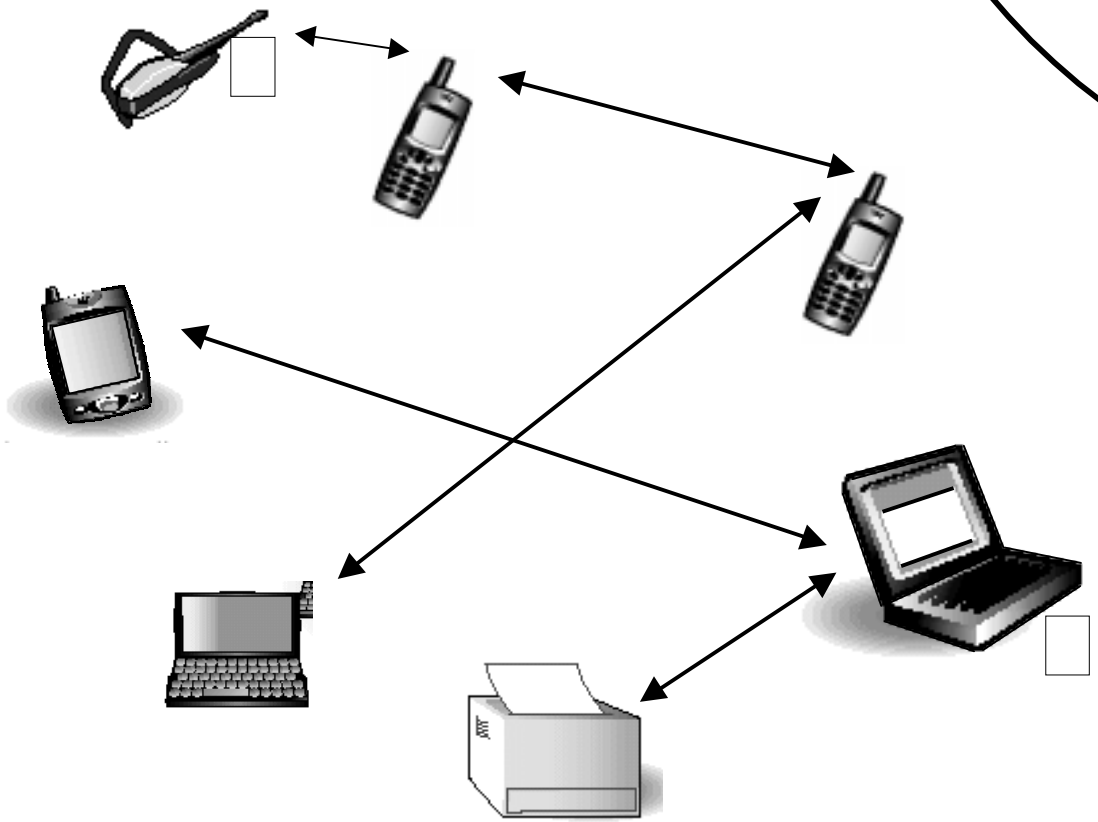
# CORE DESIGN ISSUES: mobile systems



# CORE DESIGN ISSUES: wireless extensions



# CORE DESIGN ISSUES: ad-hoc systems



# CORE DESIGN ISSUES: ad-hoc connectivity

**Definition:**

*In an ad-hoc network, there is no (wired) infrastructure to support the connectivity of the portable units.*

# CORE DESIGN ISSUES: ad-hoc connectivity

**no basestations or terminals**

**no up or downlinks**

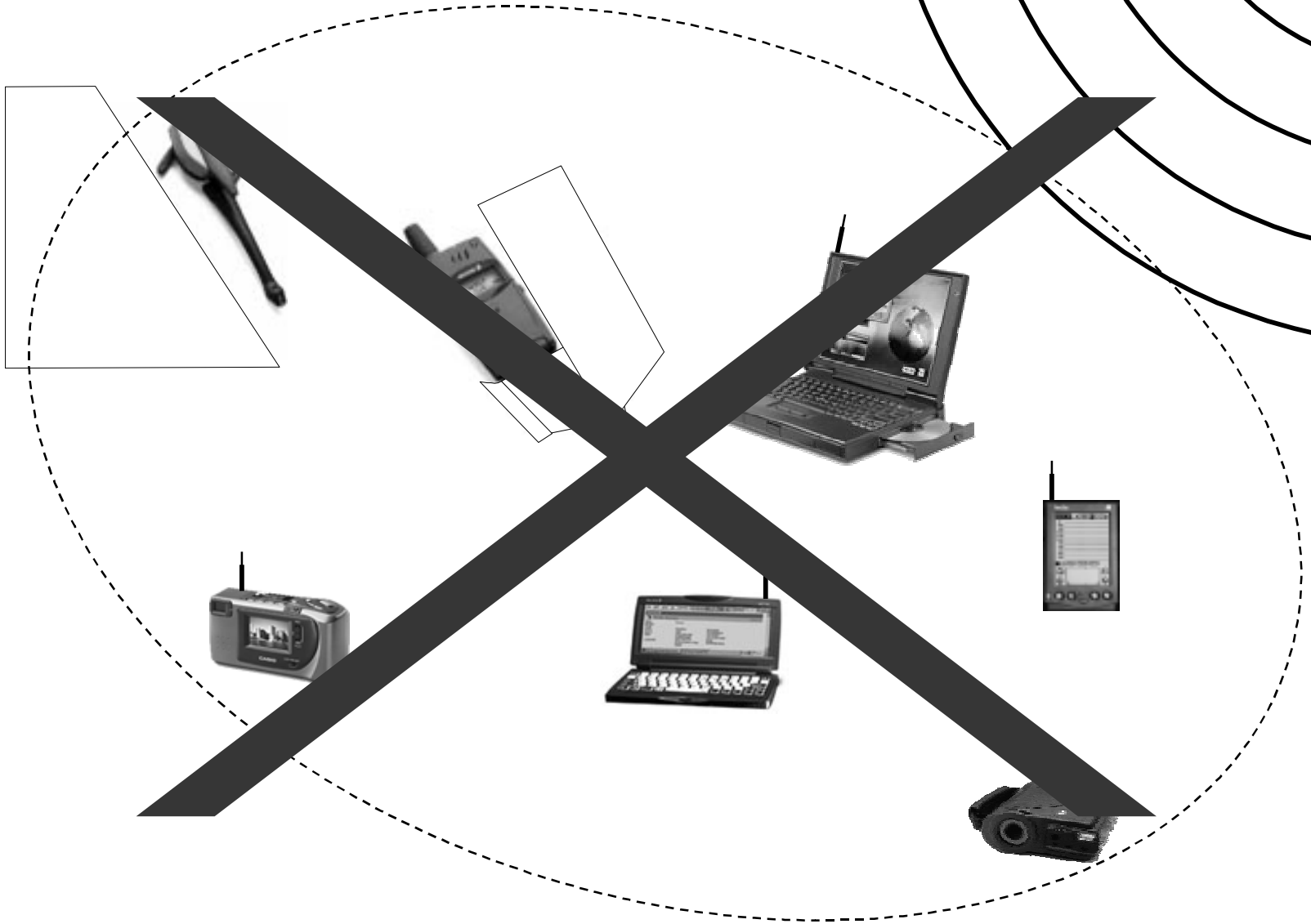
**no central controller**

**no control channel to lock to**

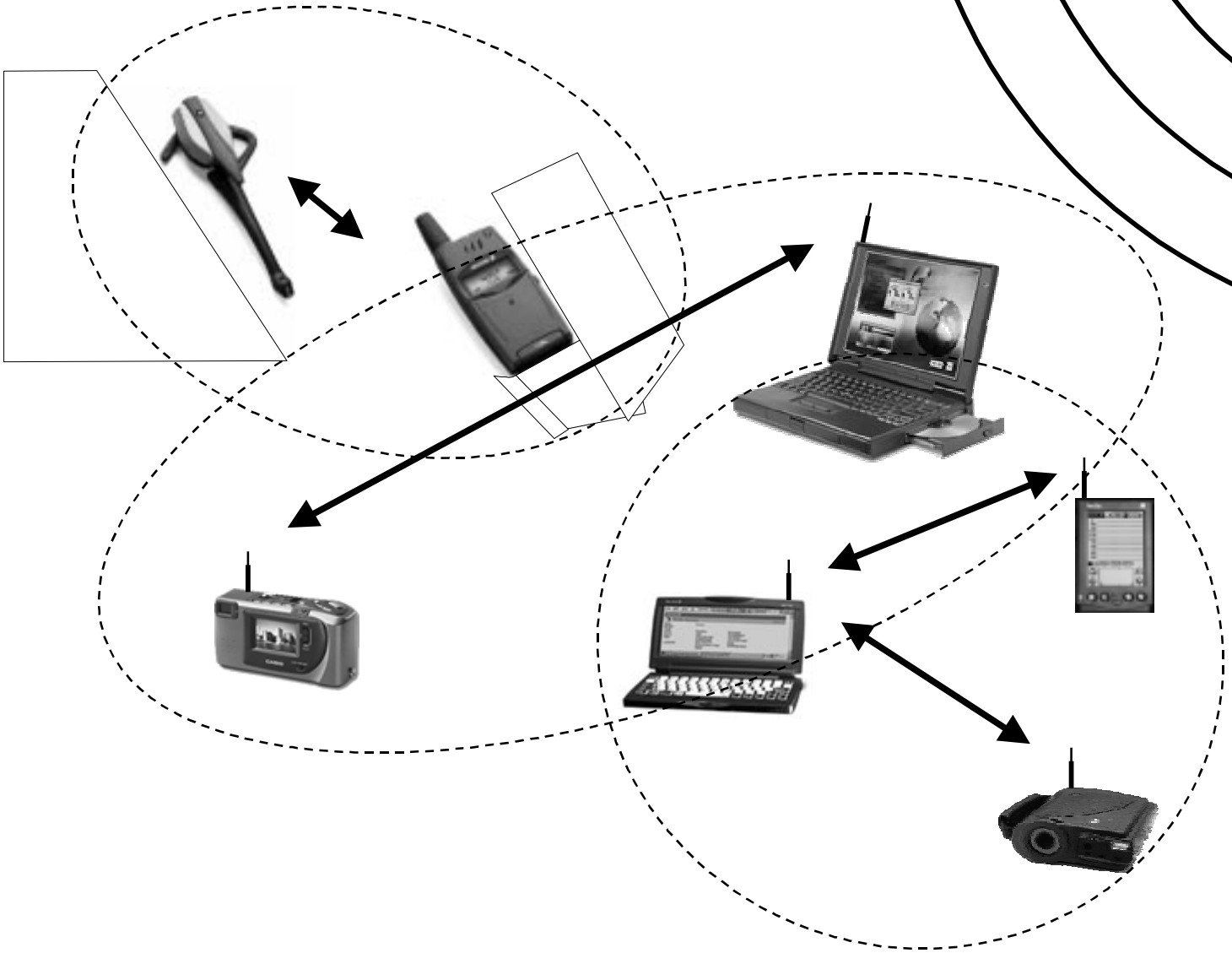
**no distinct cells**

**PEER-TO-PEER CONNECTIONS**

# CONVENTIONAL AD-HOC NETWORK

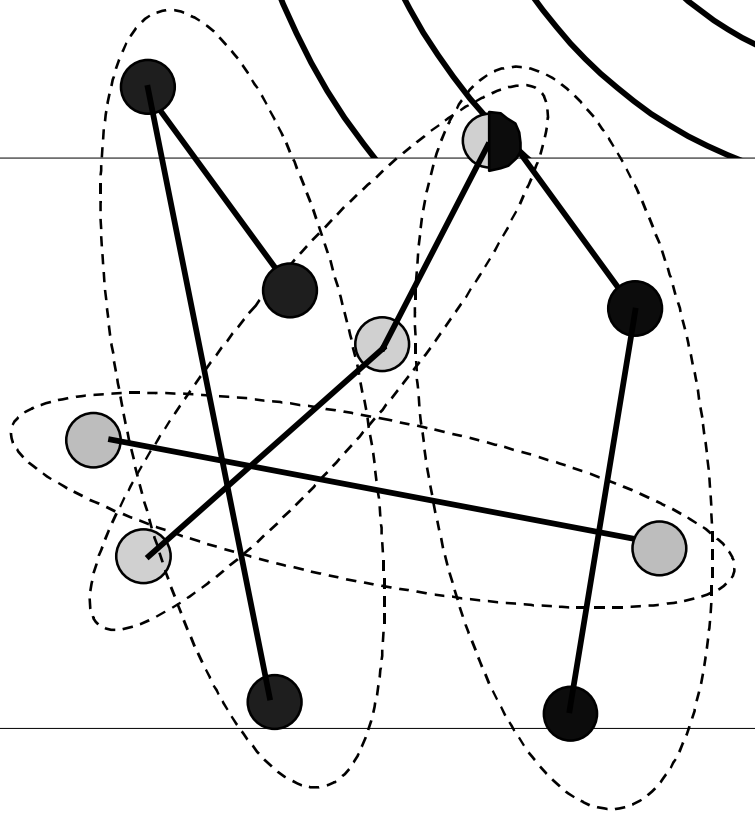


# SCATTER AD-HOC NETWORK



# CORE DESIGN ISSUES: ad-hoc connectivity

- **Scatternet ‘chaos’**
  - uncoordinated channels
  - TX powers vary
  - irregular traffic
  - near-far problems
  - non-stationary



**ROBUSTNESS**

**GRACEFUL DEGRADATION**

# CORE DESIGN ISSUES: ad-hoc connectivity

- Channel definition & allocation (MA)
- Medium access (MAC)
- Call setup
- Power management (standby)
- Traffic management (QoS)

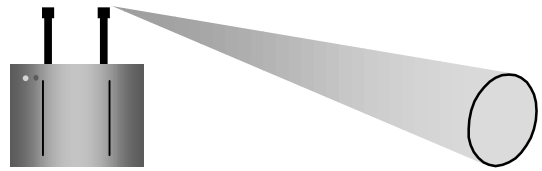
# CORE DESIGN ISSUES: radio spectrum

- Global availability
- Unlicensed
- Non-dedicated (e.g. DECT, HIPERLAN)
- Co-existing and sharing with other applications
- Regulatory bodies: FCC/ETSI/ARIB

**Industrial - Scientific - Medical (ISM) band**

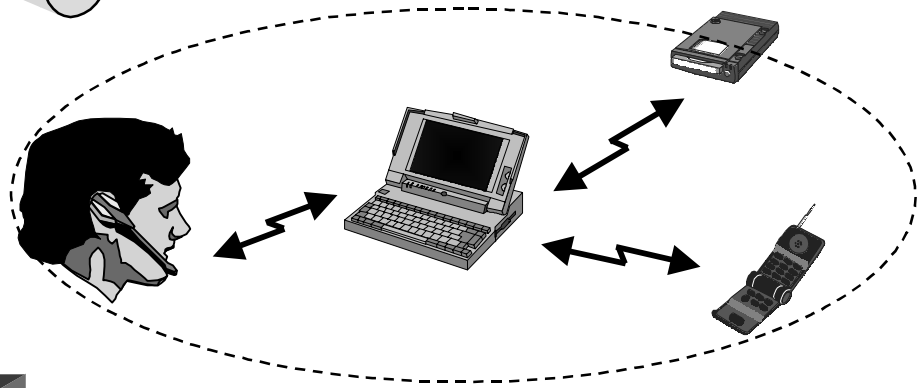
**2400-2483.5 MHz**

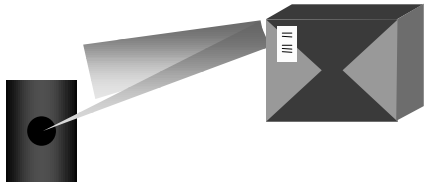
# CORE DESIGN ISSUES: spectrum sharing



WLAN

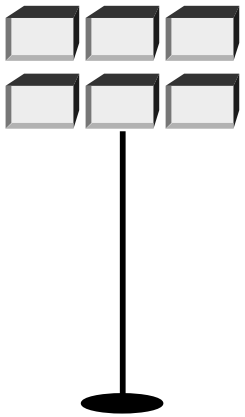
µwave ovens





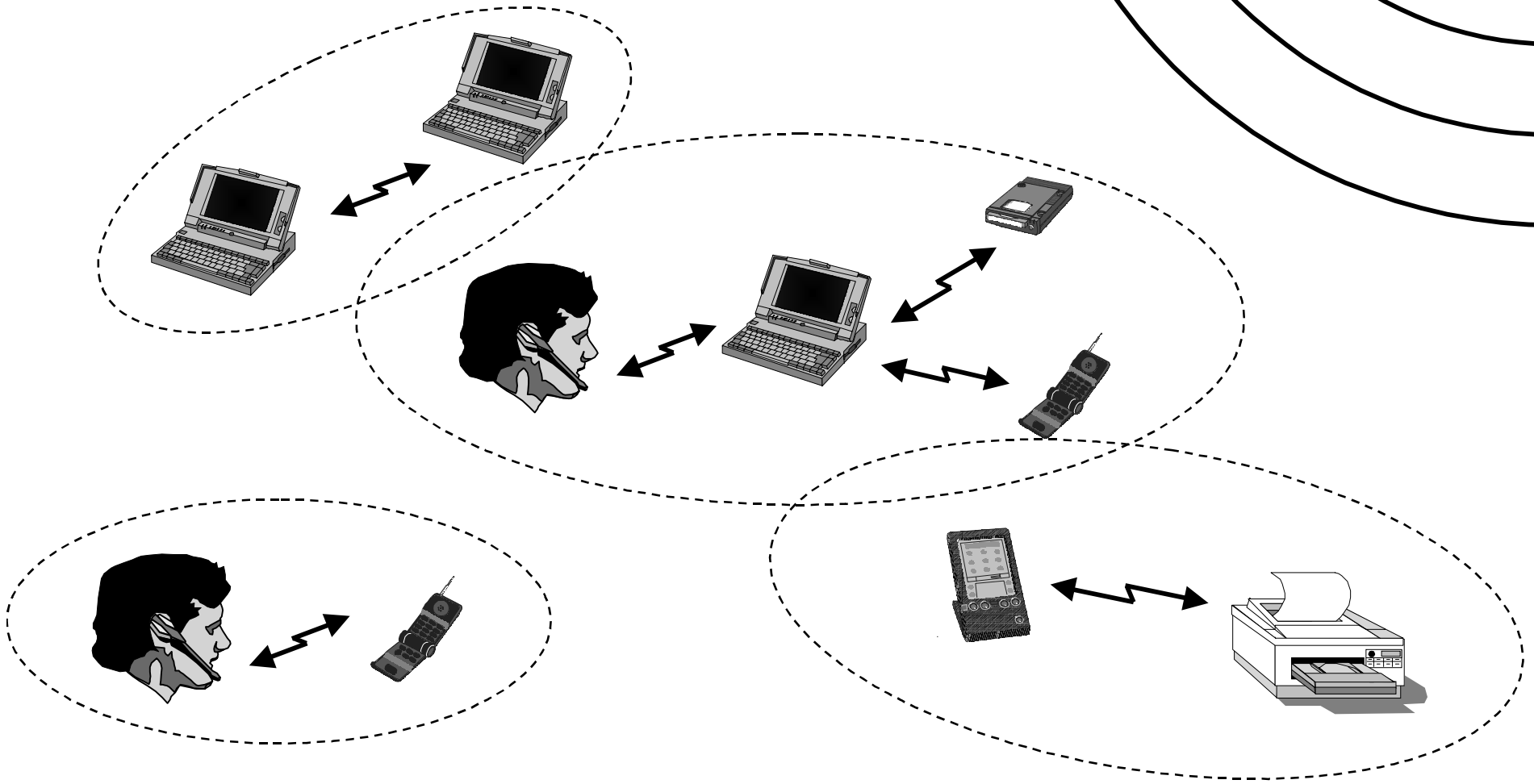
RF identification

?



RF lighting

# CORE DESIGN ISSUES: spectrum sharing



# CORE DESIGN ISSUES: spectrum

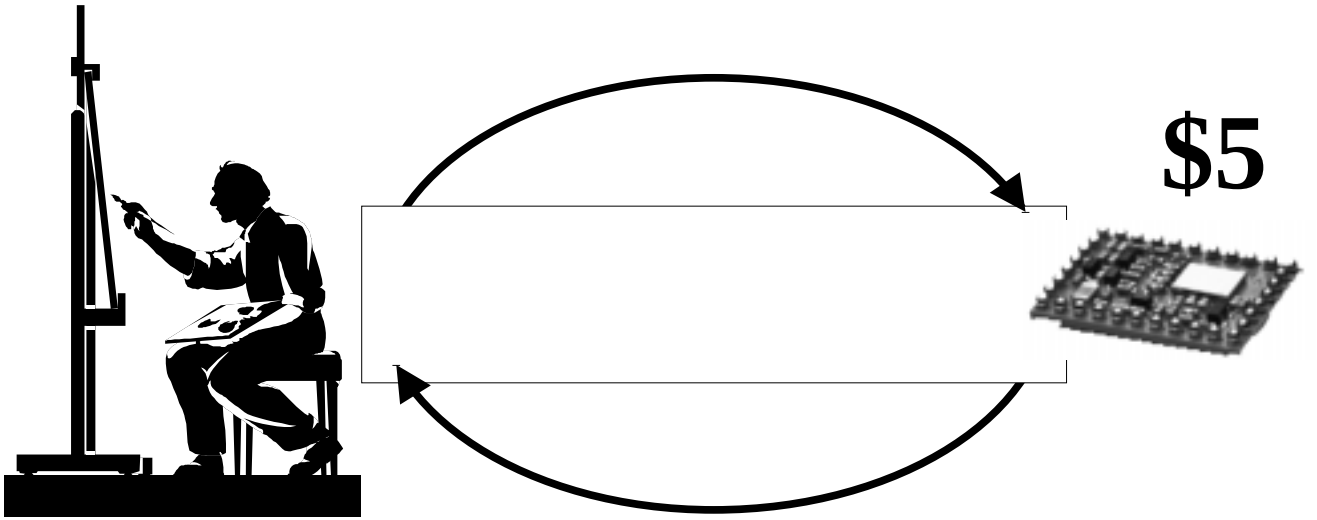
- **Knowns**
  - 2.45 GHz ISM band applicable wordwide (almost)
  - regulatory rules (FCC Part 15, Part 18, ETSI, ARIB)
  - existing non-Bluetooth systems
  - a new system introduction any time, any where

- **Unknowns**
  - rule changes
  - new systems and their deployment

**ISM STATUS IS UNPREDICTABLE**
**PREPARE FOR THE WORST**

# CORE DESIGN ISSUES: low cost

- Prepared for single-chip integration
- Main-stream technology




air protocol design

transceiver design

# APPLICATION AREAS

# APPLICATIONS AREAS

- Personal net (PNET)
- Person-to-person net (PPNET)
- Mobile person-to-Internet access
- Person-to-local access point
- Future applications

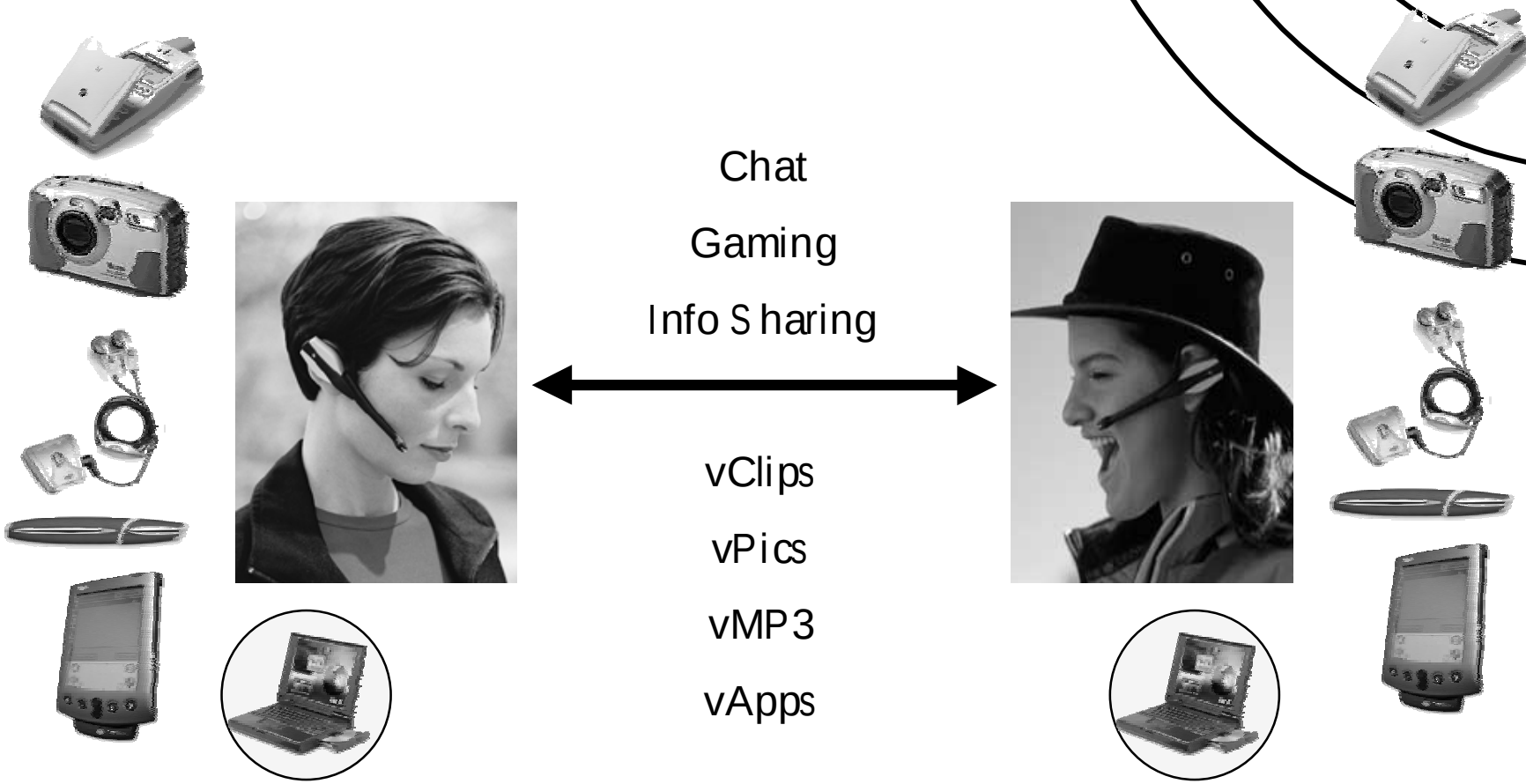
# APPLICATION AREAS: personal net (PNET)

**Ultra portable devices:**

- **Pen input**
- **Voice input/output**
- **Exchange/share data between devices**

= Potential Bluetooth and WLAN device

# APPLICATION AREAS: person-to-person net (PPNET)




= Potential Bluetooth and WLAN device

# APPLICATION AREAS: mobile person-to-Internet access

Browse

Mail

Data Access /storage

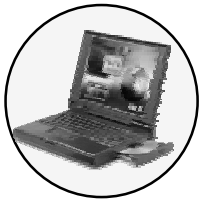
Send Postcards

Maps

Voice/text input

Streaming voice and video

# APPLICATION AREAS: person-to-local access point



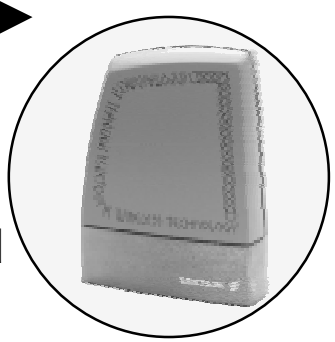
Local Information Push/Retrieval

M-Commerce

WAP

Mail/Data Access and Storage

Multi media messaging



Local data

WWW

= Potential Bluetooth and WLAN device

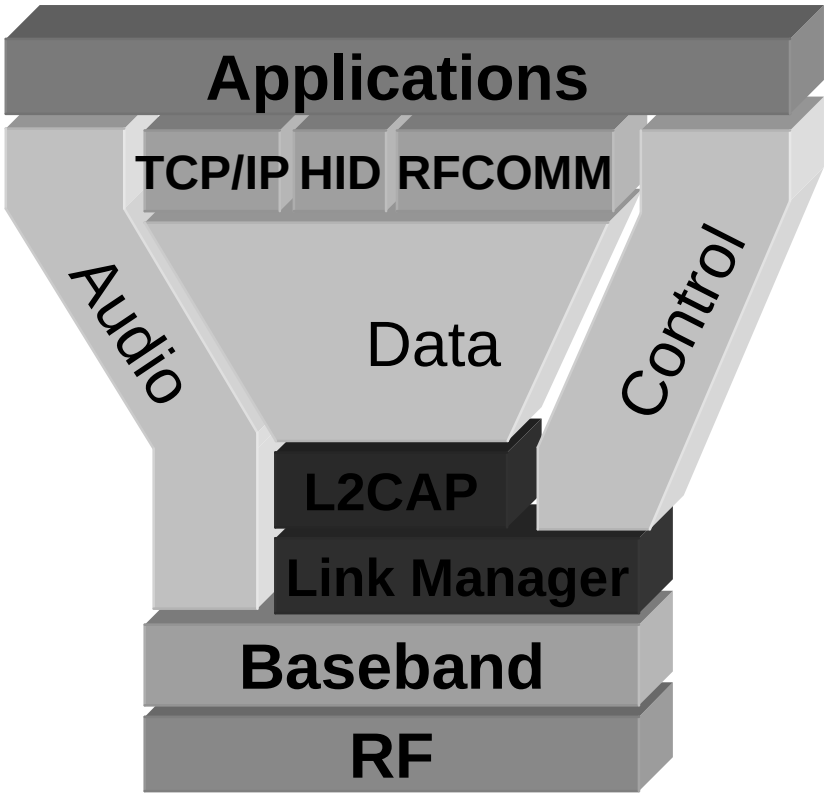
# APPLICATIONS AREAS: future applications

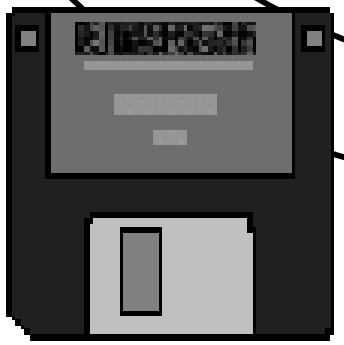
- Home automation
- Home entertainment
- Electronic commerce
- Industrial control
- Automotive
- Surveillance
- Access control
- and countless others…

# PROTOCOL STACK

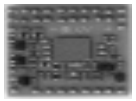
- **Adapted OSI model**
- **Implementation & low-power considerations**
- **Two major segments:**
  - Application frame work
  - Hardware description

# PROTOCOL STACK: hardware & software description



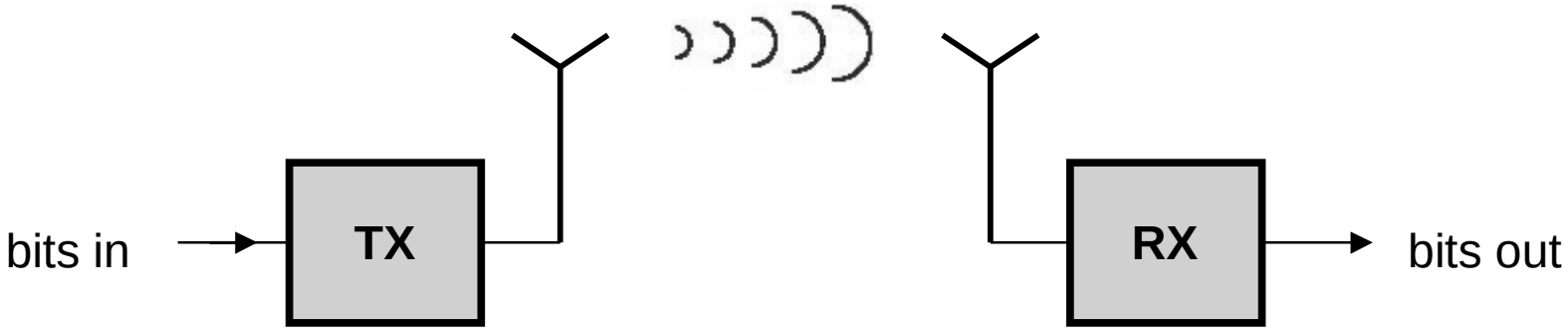
an application framework



a hardware description

# PROTOCOL STACK: RF layer

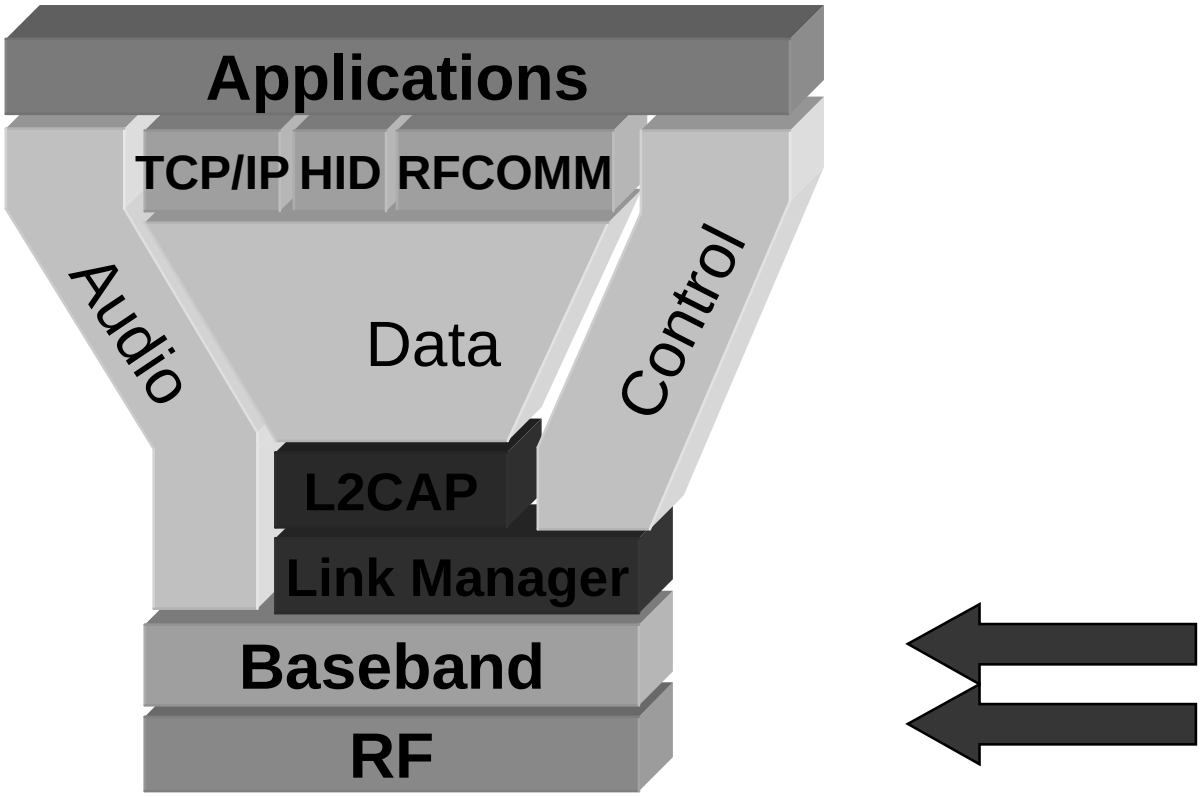
- **Basic radio functions**
  - signal amplification
  - frequency synthesis
  - frequency up & downconversion
  - modulation & demodulation
  - conversion bits into symbols
  - filtering & shaping



# PROTOCOL STACK: baseband layer

- **Real-time operations**
  - time slotting
  - frequency hopping
  - synchronization
  - packet handling
  - error correction
  - basic connection establishment

# PROTOCOL STACK: RF & baseband



# SIGNAL SPREADING

- **FH spread spectrum**
  - broadband on average / narrowband instantaneously
  - filter rejection: avoiding most of the interference
  - multiple access scheme: **FH-CDMA**

## FILTER AND SURVIVE

# BLUETOOTH RADIO PARAMETERS

- **FH parameters**
  - 79 carriers, spaced at 1 MHz
    $2.402 + k$ MHz, $k = 0, \ldots, 78$
  - lower guard space: 1.5 MHz
  - upper guard space: 3 MHz
  - 1600 hops/s nominal hop rate

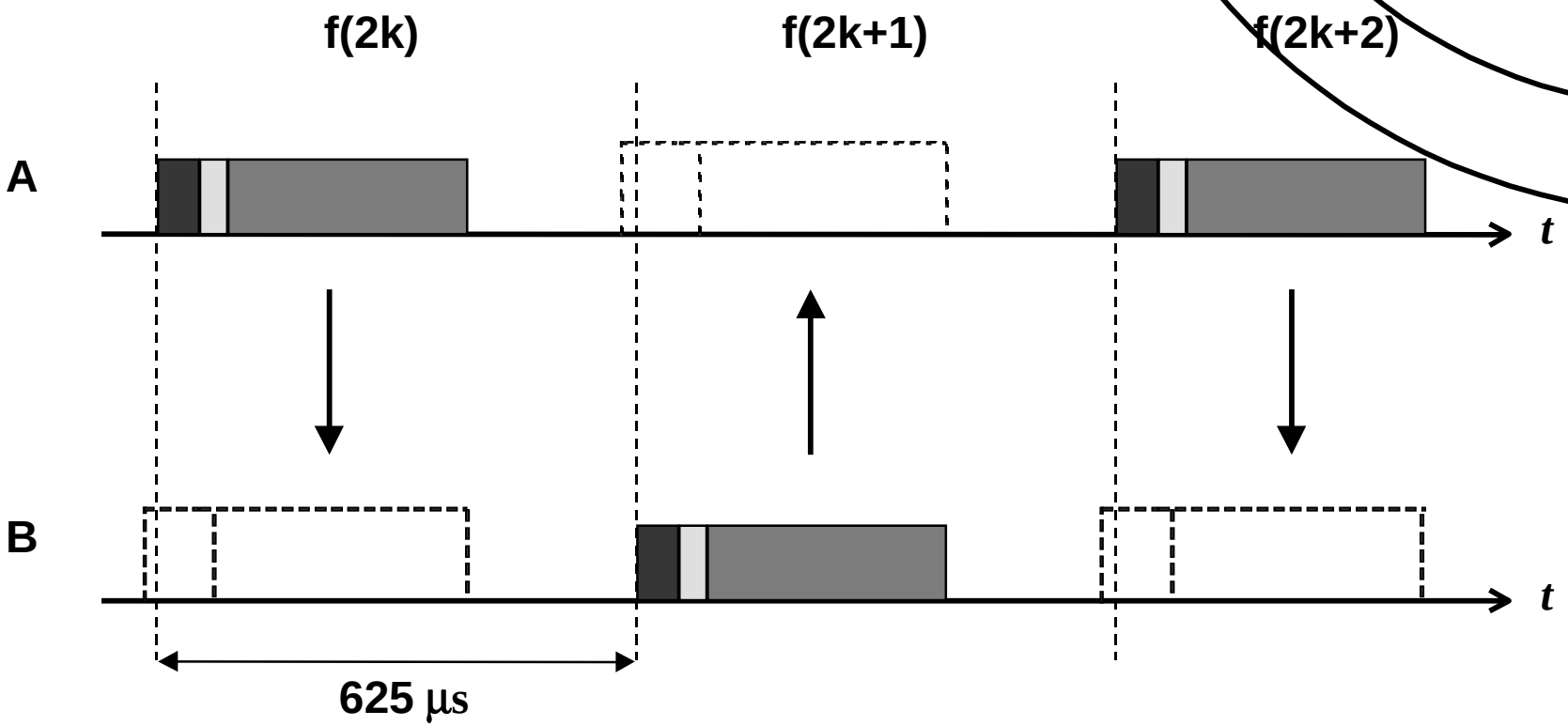
# BLUETOOTH RADIO PARAMETERS

- **Modulation parameters**
  - 1 Ms/s FSK modulation: $0.28 < h < 0.35$
  - Gaussian shaping GFSK: $BT = 0.5$
  - 1 Mb/s nominal bit rate
  - 20dB spectral bandwidth: 1 MHz

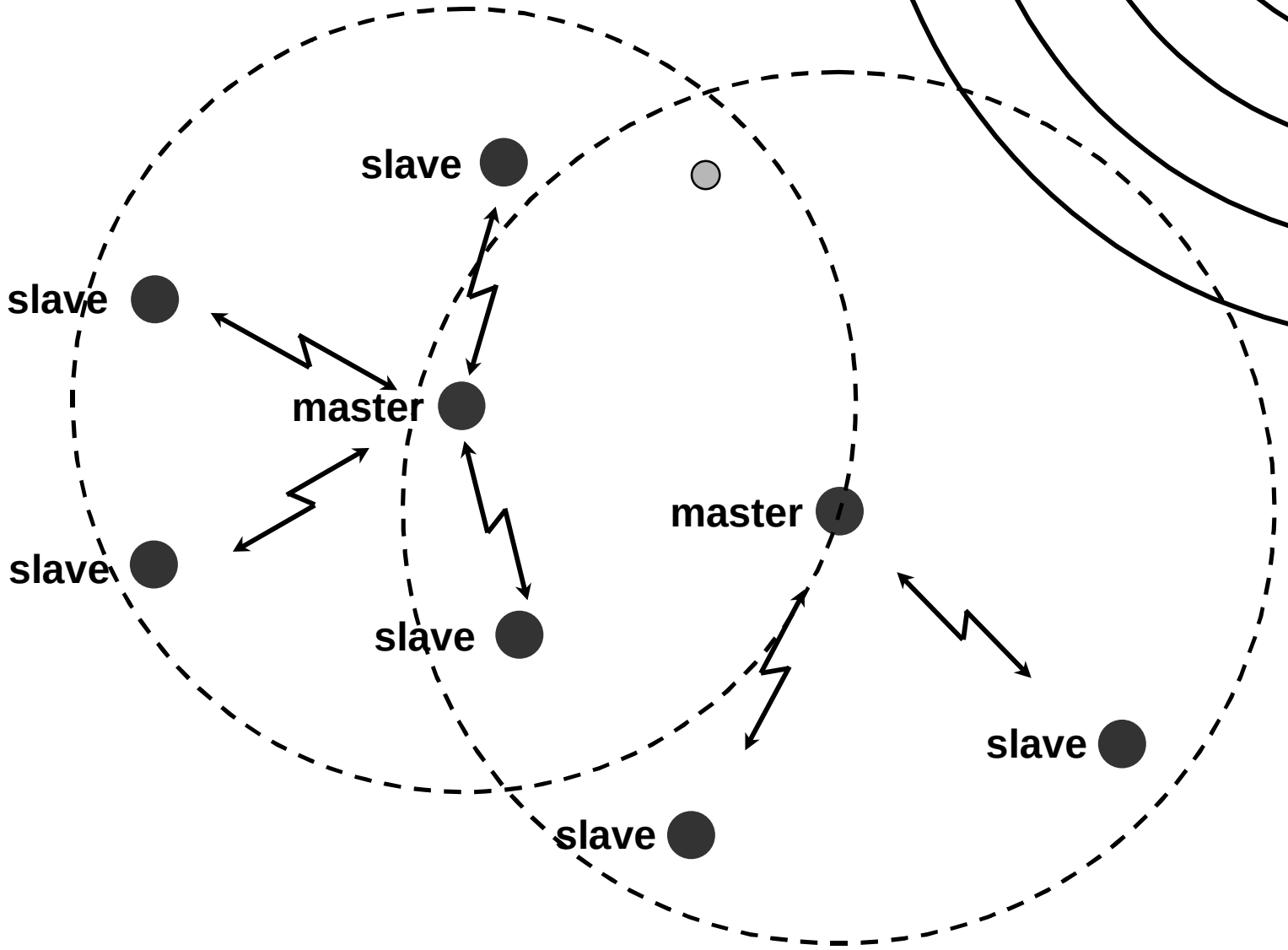
# THE BLUETOOTH CHANNEL

- Time slotted
- Time division duplex (TDD)
- $T_{slot} = T_{dwell}$

# FH/TDD CHANNEL



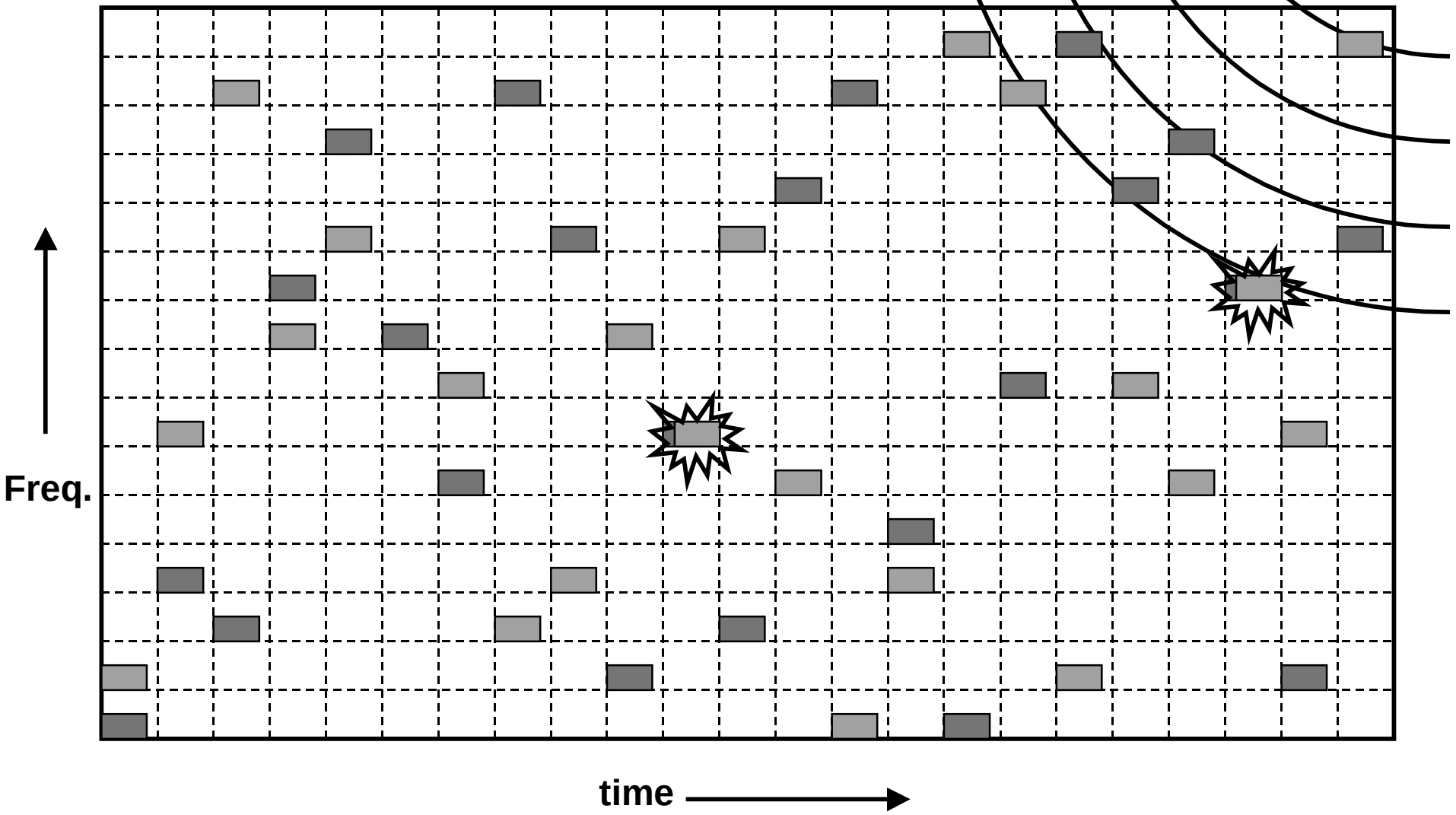
# PICONET CHANNELS



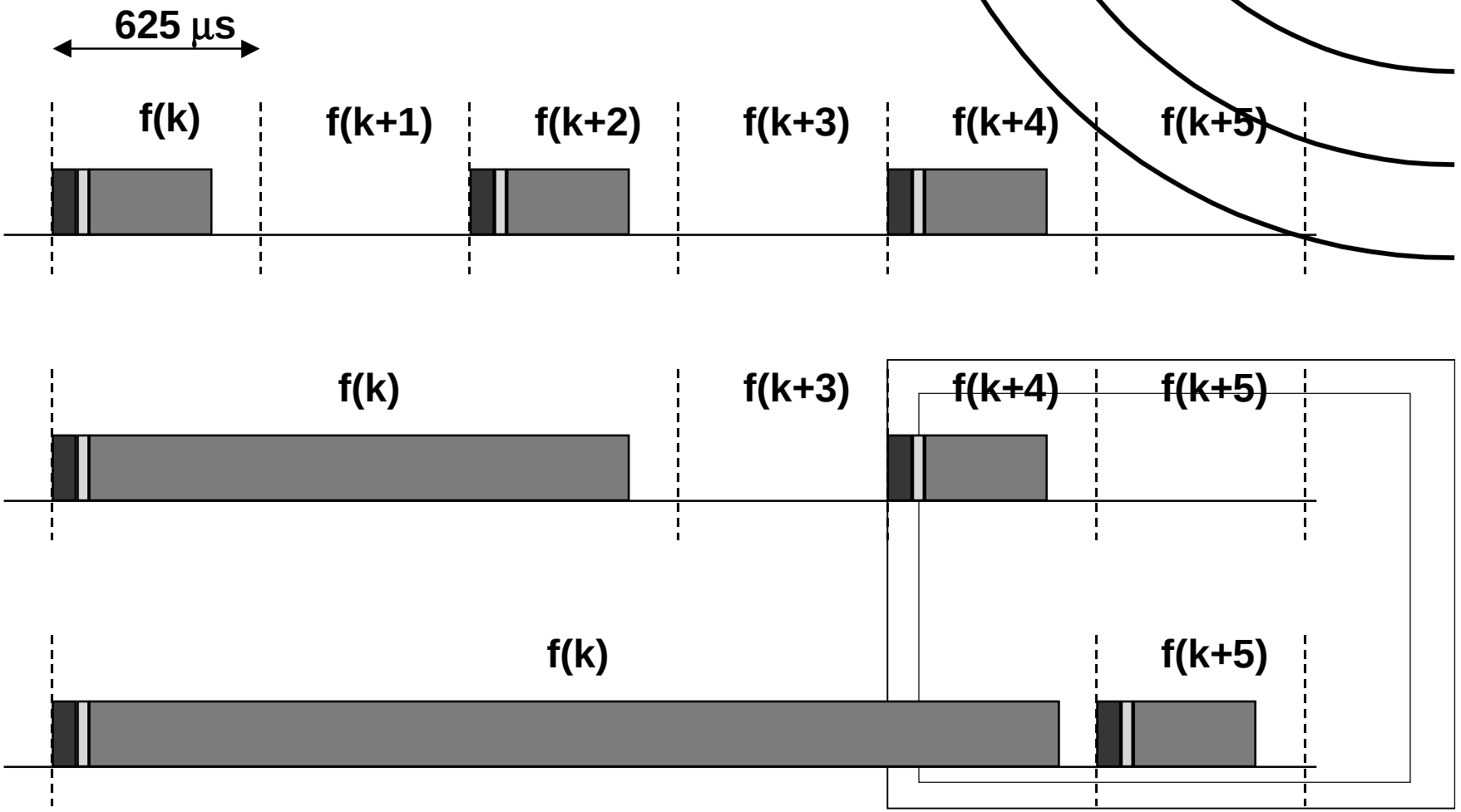
# MASTER-SLAVE CONCEPT

- Only roles during piconet existence
- Any unit can become master, but only one per piconet
- Master defines piconet channel
- Master controls traffic on channel
- Master provides QoS

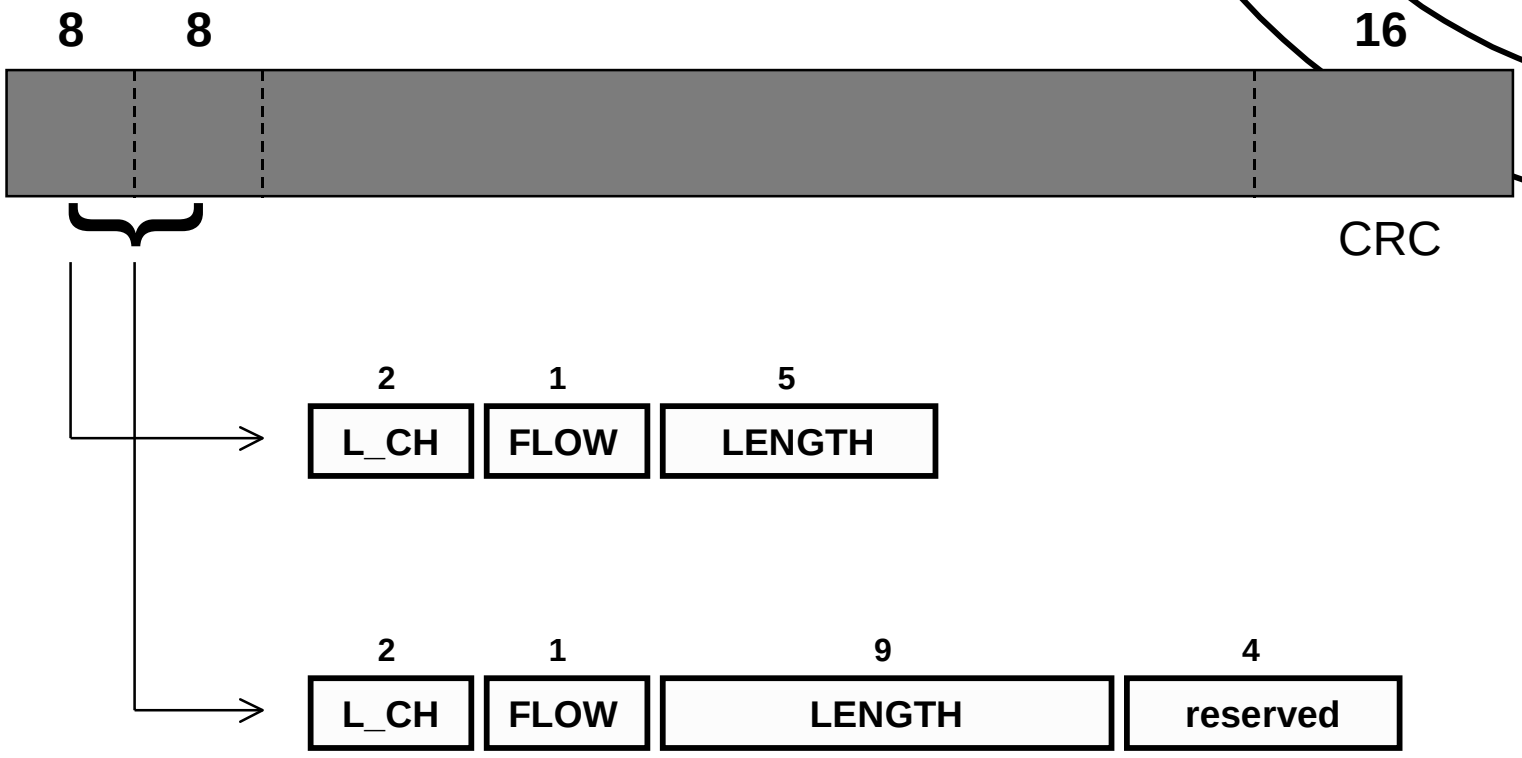
# EXPLOITING 79 MHz OF SPECTRUM



# MULTI-SLOT PACKETS



# PAYLOAD FORMAT



# PHYSICAL LINKS

- **Multi-media support**
  - synchronous services
  - asynchronous services
  - isochronous services

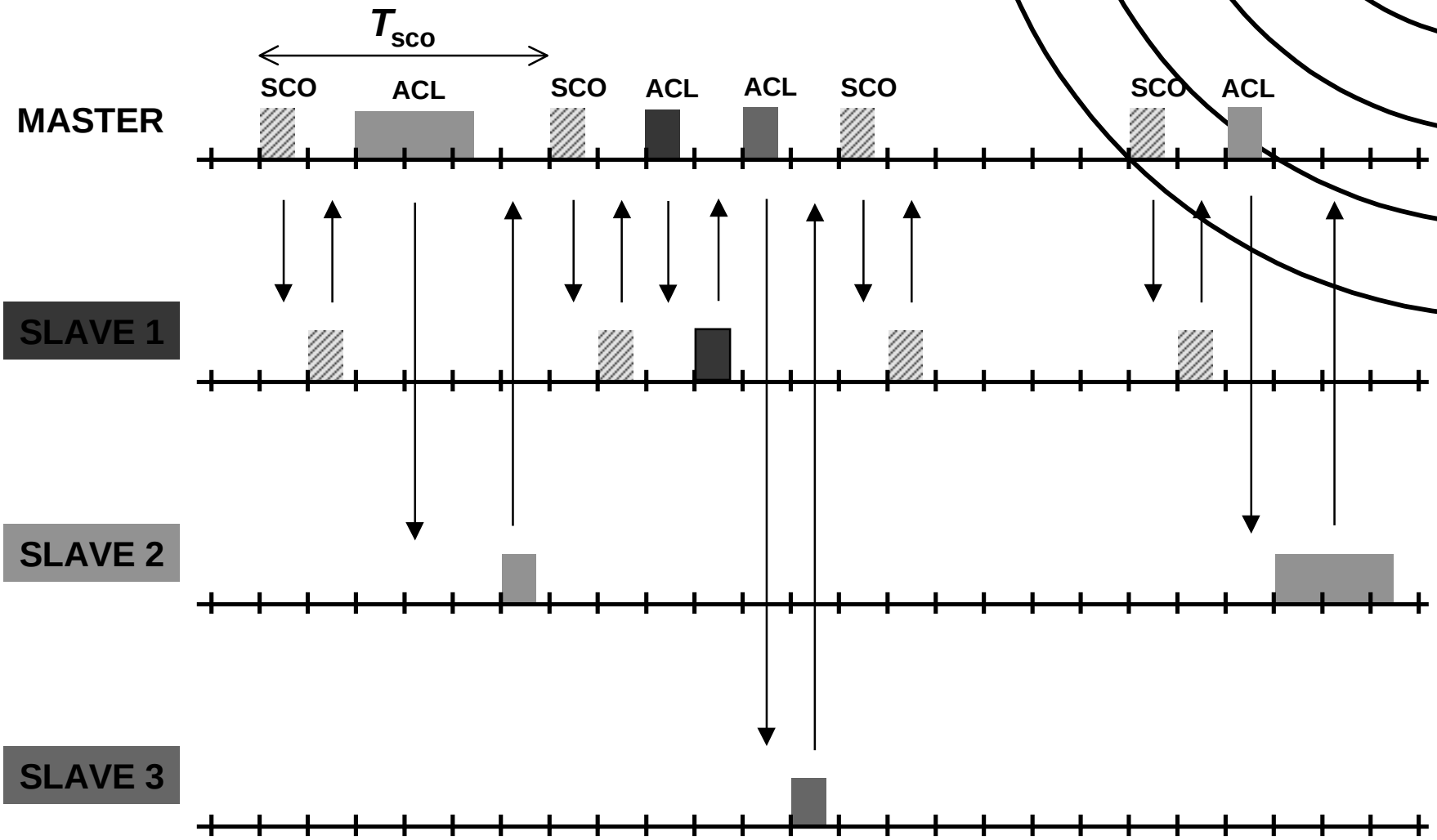
# PHYSICAL LINKS

- **Synchronous services**
  - circuit switching
  - point-to-point
  - no delay variations, error tolerant
- **Asynchronous services**
  - packet switching
  - point-to-multipoint
  - delay tolerant, no errors
- **Isochronous services**
  - point-to-point
  - delay & error tolerant

# PHYSICAL LINKS

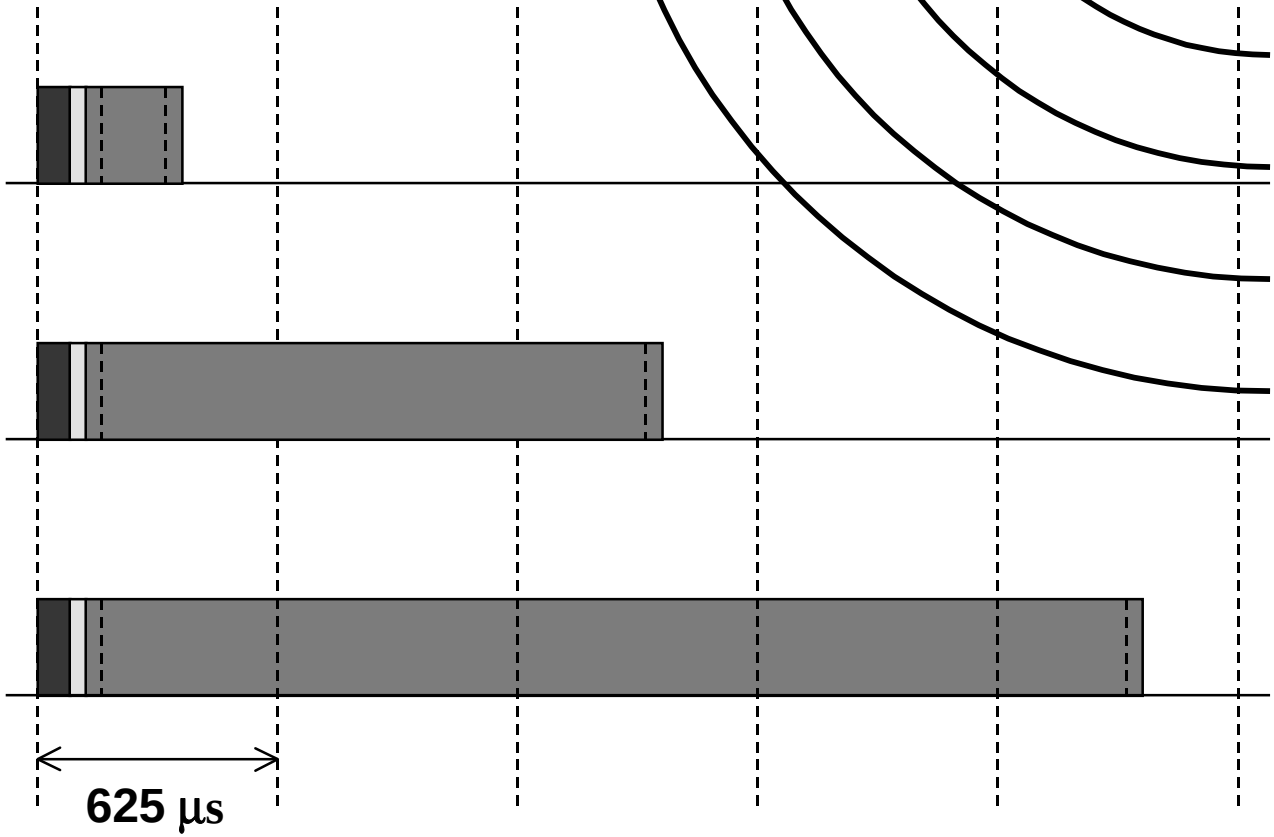
- **Mixing services on air interface**
  - time slotted channel
  - packet scheduling by master
  - control over quality of service
- **Synchronous Connection-Oriented (SCO) Link**
  - symmetric, synchronous services
  - slot reservation with fixed interval
- **Asynchronous Connection-Less (ACL) Link**
  - (a)symmetric, asynchronous services
  - polling access scheme
  - isochronous service via master scheduling

# MIXING SERVICES



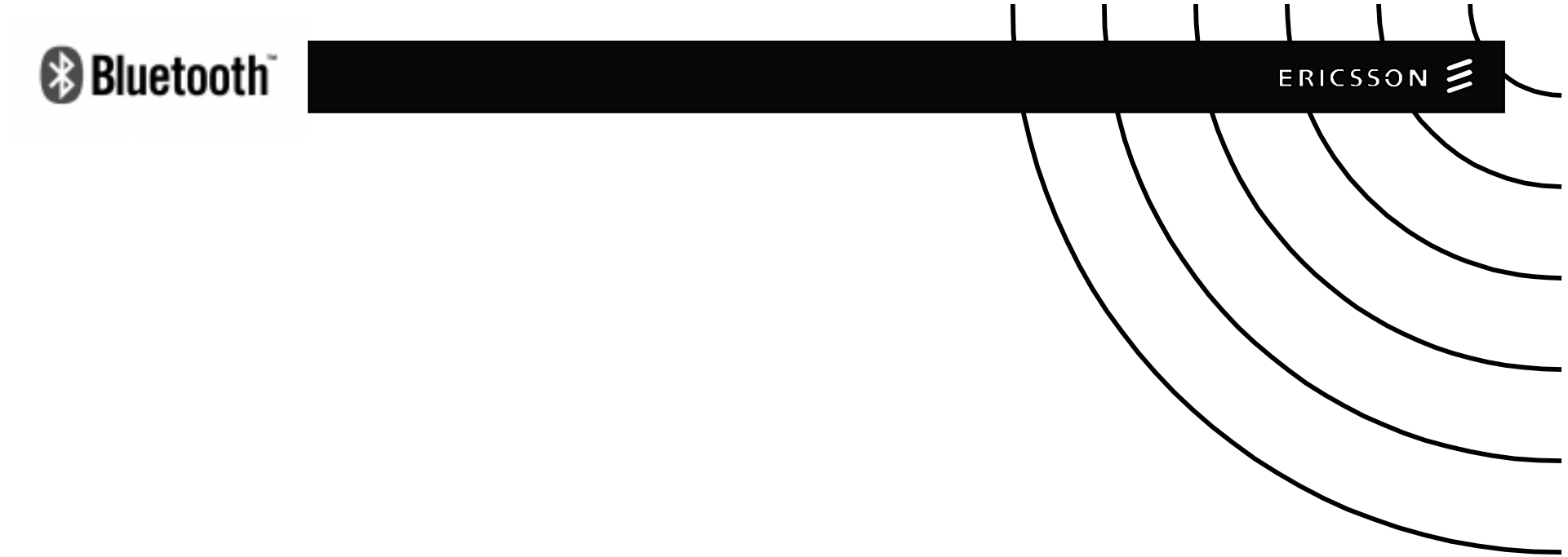
# ACL PACKETS

- **DM1*, DH1****
- **DM3, DH3**
- **DM5, DH5**



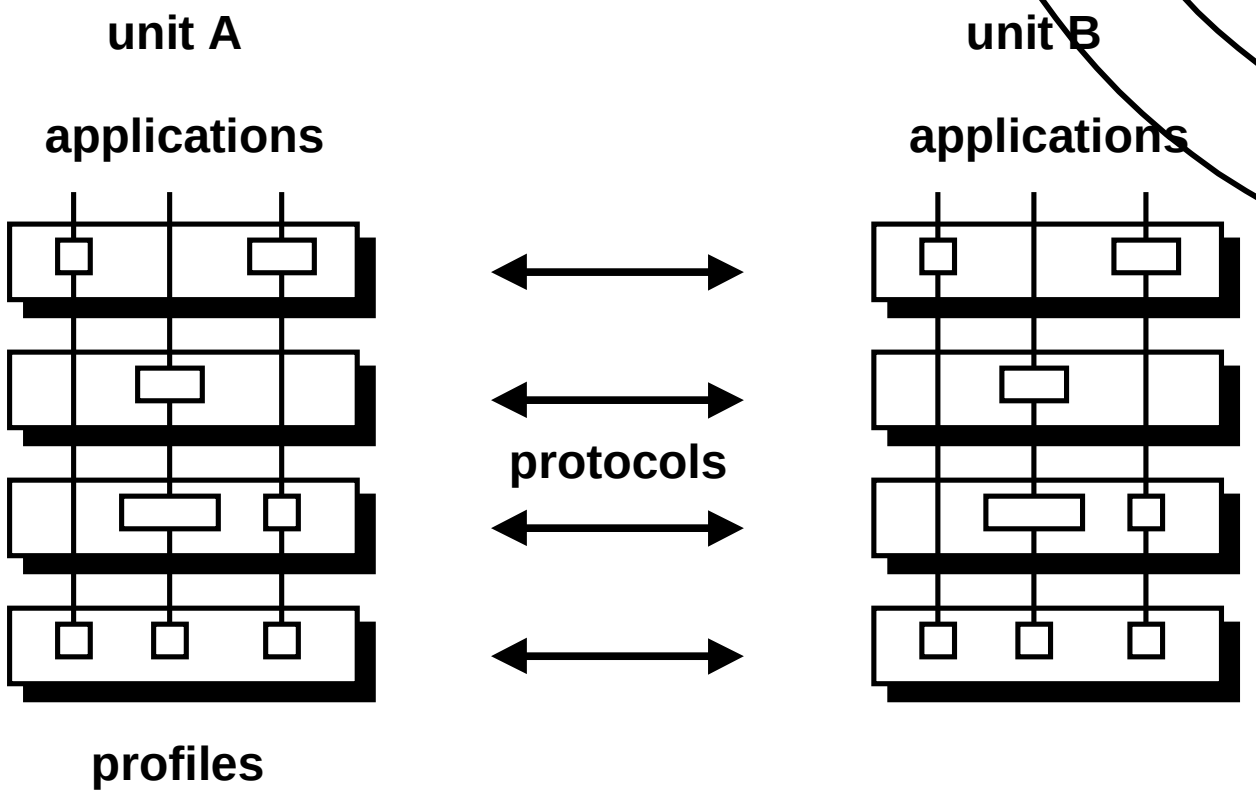

* DM1 is a common packet

** DH packet: uncoded
DM packet: 2/3-rate coded; shortened (15,10) Hamming code

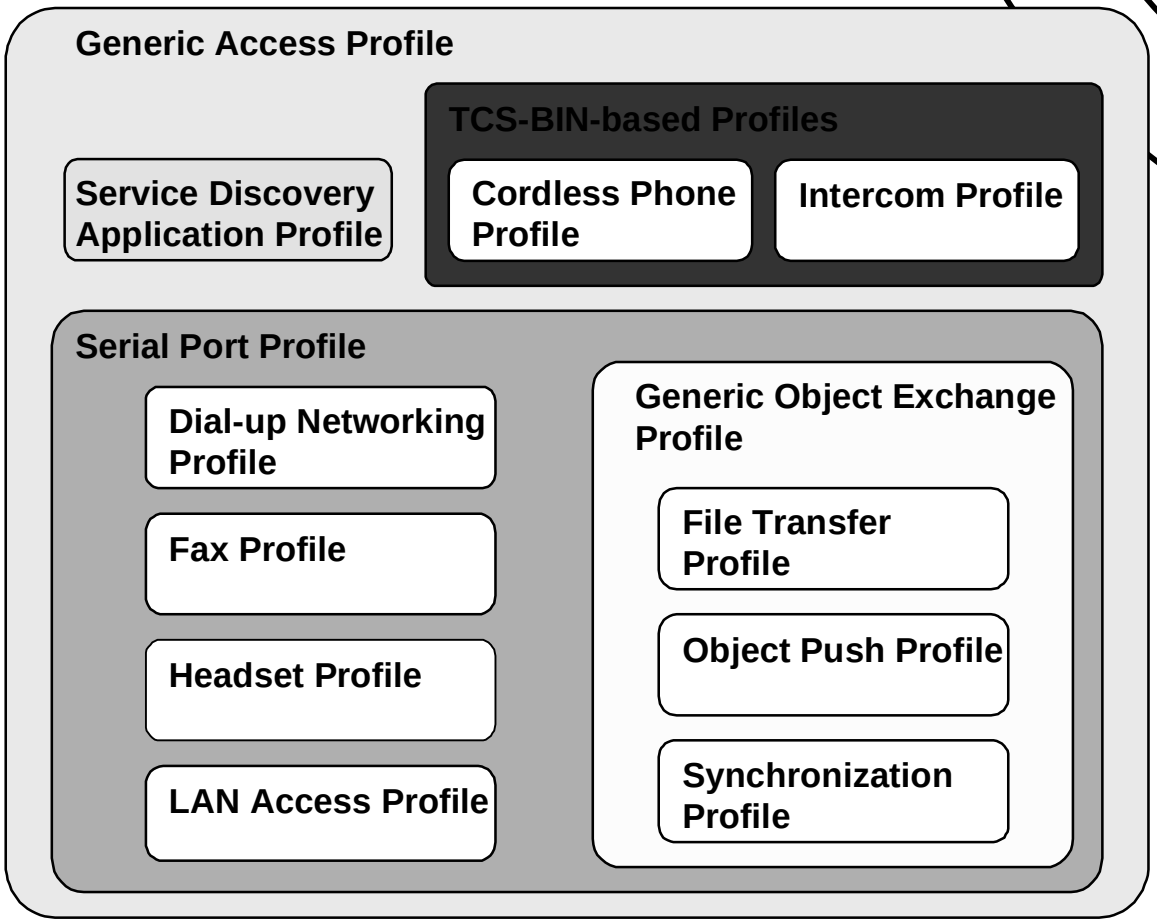



# PROFILES

# PROFILES & PROTOCOLS



# BLUETOOTH PROFILES



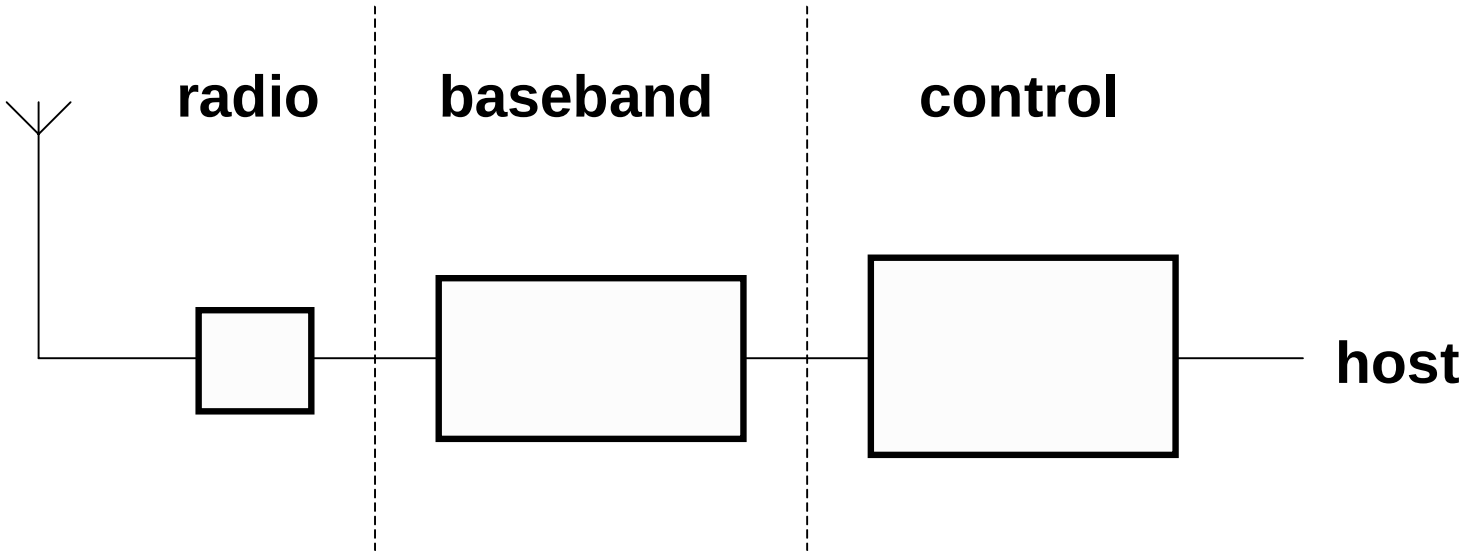
# IMPLEMENTATION ISSUES

# BLUETOOTH IMPLEMENTATION

- low-cost
- low-power
- HW/SW separation

# BLUETOOTH IMPLEMENTATION

- radio: analog circuitry
- baseband: dedicated logic
- control: general purpose processor



# IMPLEMENTATION: low cost

- main stream technology
- single-chip solution
- simplicity

# IMPLEMENTATION: low power

- low voltage
- smart partitioning
- smart processing
- single chip

# CROSS-INDUSTRY COLLABORATION

- **Promoters**
  - 3COM
  - Ericsson
  - IBM
  - Intel
  - Lucent
  - Microsoft
  - Motorola
  - Nokia
  - Toshiba
- **2000+ adopters**


SOLVED