Wireless Sensor Networks

11th Lecture

29.11.2006

University of Freiburg
Computer Networks and Telematics
Prof. Christian Schindelhauer

Christian Schindelhauer

schindel@informatik.uni-freiburg.de

Bluetooth in WSN?

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

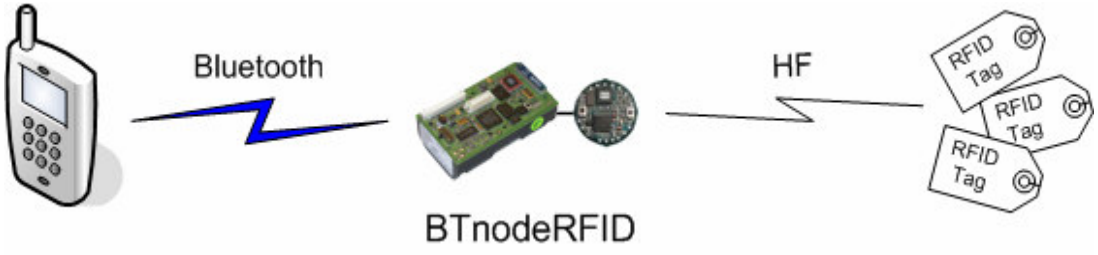
- **There are several commercially available MAC protocol/products**
  - Wi-Fi
  - Bluetooth

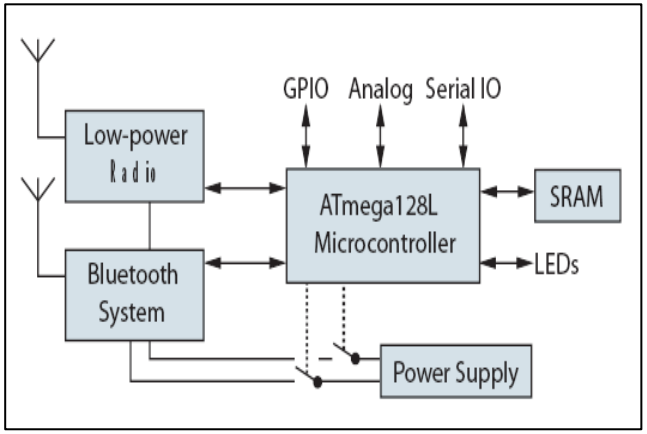
- **Why not Bluetooth in WSN?**
  - The need to constantly have a master node
  - Limited number of active slaves per piconet
  - Active slave must always be switched on
  - Passive slave has to apply at master to be active slave
  - Complexity
  - Tight synchronization among nodes in piconet

However…

- **Strong points:**
  - Spread Spectrum radio
  - Mass production: ensures robustness and reduces cost

- **Dual-radio BTnodes (research at ETH Zürich):**
  - Bluetooth subsystem
  - Low-power radio
  - Scatternets with max. 4 Piconets





Understanding Bluetooth

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

- **Bluetooth Characteristics**
- **Protocol Stack**
- **Architecture:**
  - Piconets
  - Scatternets
- **Radio Specifications**
- **Baseband Specifications**
  - FHSS and TDD
- **Packet Formats**
- **Error Correction**

Characteristics

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

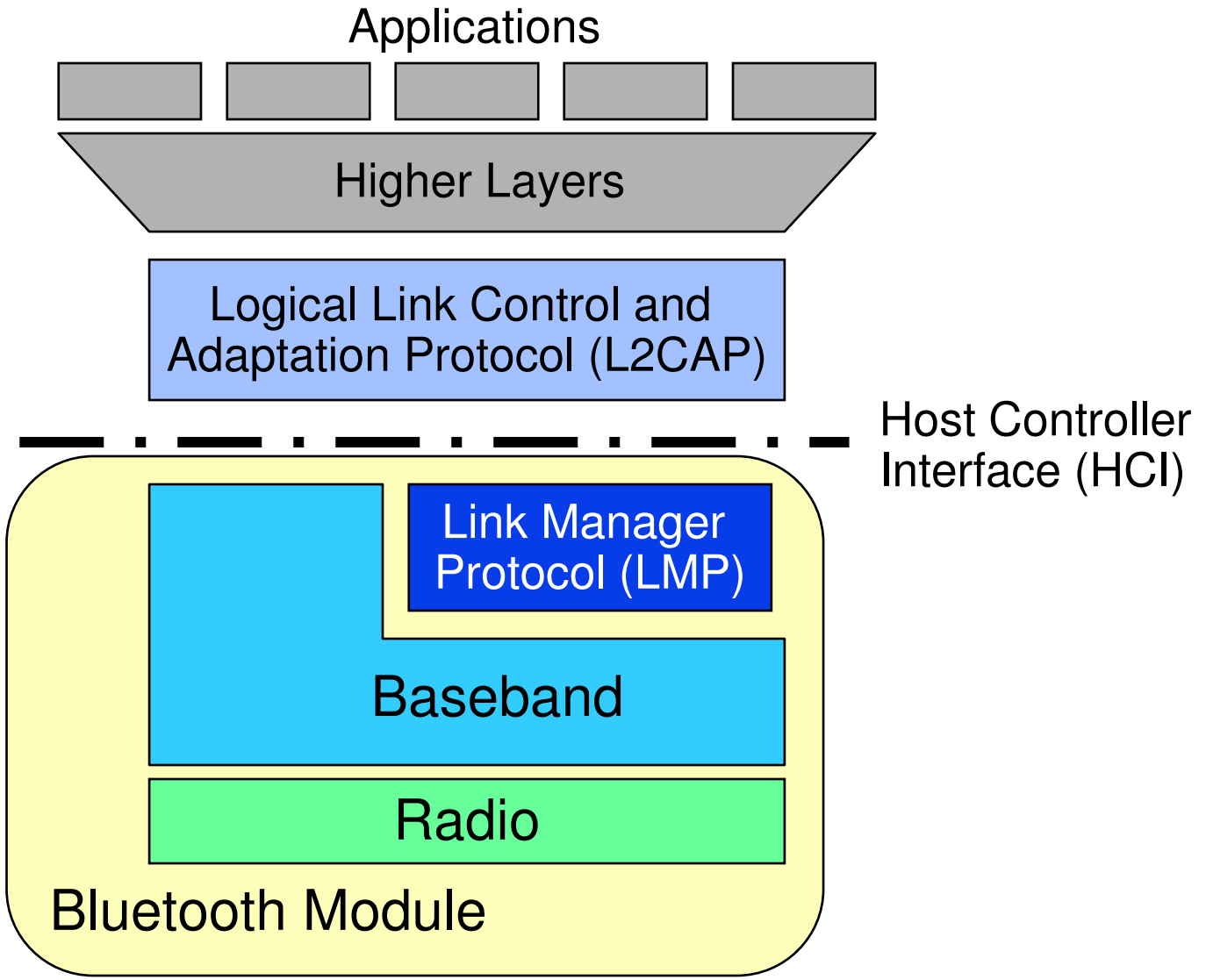
- **Initial goal: Cable replacement**
- **Operates in the unlicensed ISM 2.4 GHz range, using FHSS**
- **Short communication range**

Class	Maximum Permitted Power (mW)	Maximum Permitted Power (dBm)	Range (approximate)
Class 1	100 mW	20 dBm	~100 meters
Class 2	2.5 mW	4 dBm	~10 meters
Class 3	1 mW	0 dBm	~1 meter

- **Asynchronous (data) and synchronous (voice) service supported**
- **Data rate**
- **No need for infra-structure**
- **Low power consumption**

Lower Layer Protocols

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer



Network Topologies

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

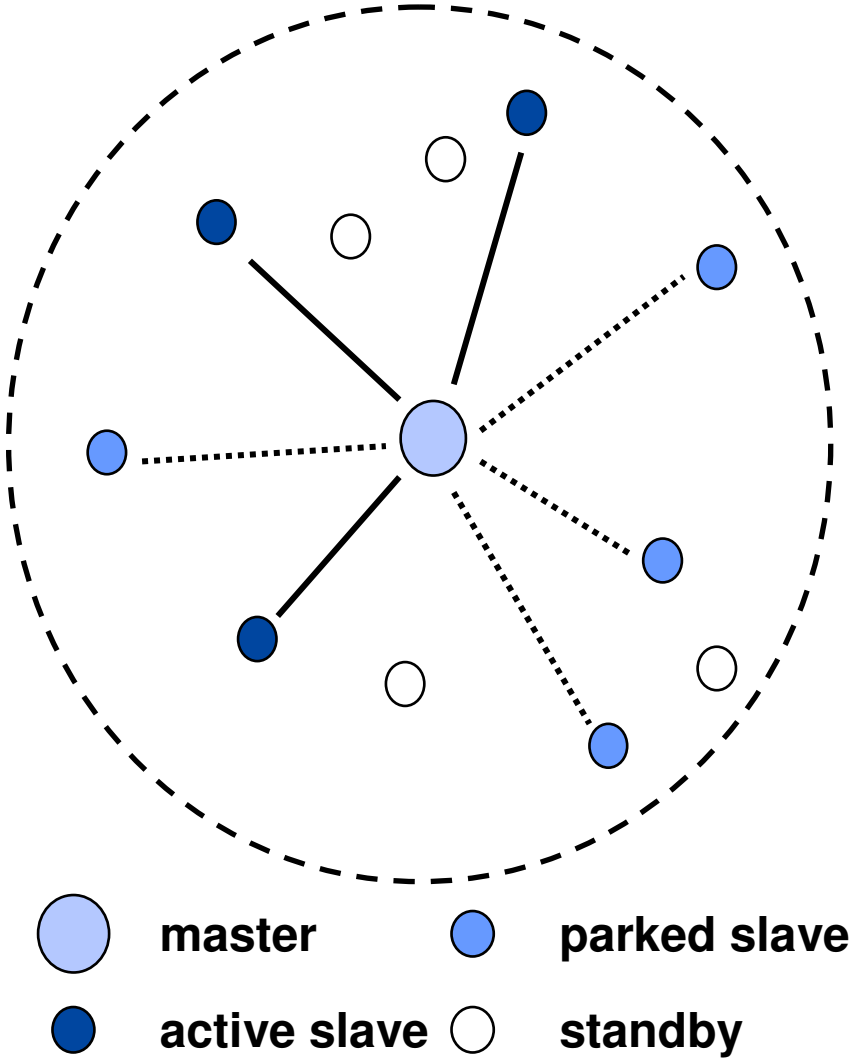
- **Conventional ad hoc network**

- **Bluetooth**

Piconet

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

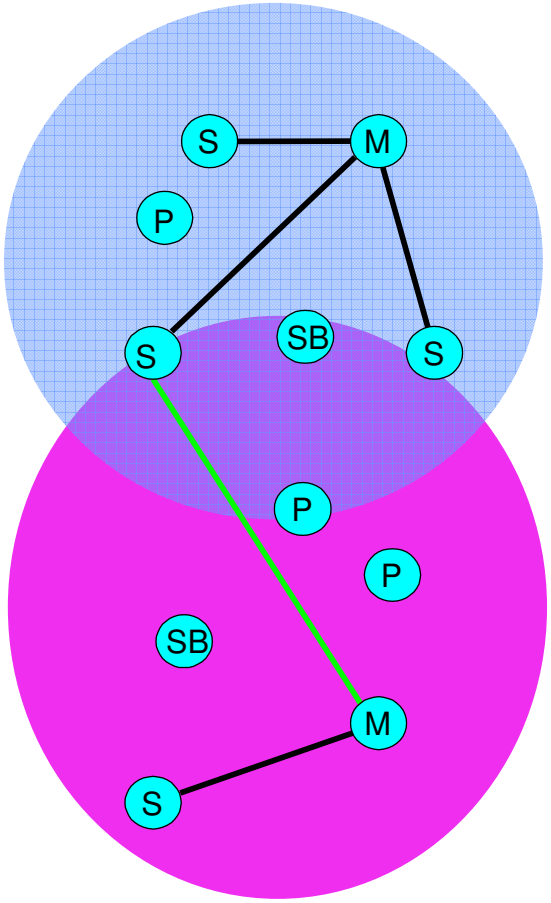
- An FH Bluetooth channel is associated with a piconet.
- Star Topology
  - 1 Master, up to 7 active slaves
  - Unlimited number of passive slaves
- Master:
  - determines hopping scheme and timing
  - Administers piconet (polling)
- Logical Channels
  - Asynchronous, packet oriented
  - Synchronous, connection-oriented (voice, slot reservation)



Scatternet

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

- **Scatternet –intersecting piconets.**
  - Devices can be slave in both or master in one and slave in other.
- **Piconets with overlapping coverage use different hopping sequences**
  - Collisions may occur when multiple piconets use the same carrier frequency at the same time
- **Devices can participate in multiple piconets simultaneously, creating a scatternet**
  - A device can only be the master of one piconet at a time
  - A device may serve as master in one piconet and slave in another
  - A device may serve as slave in multiple piconets



M=Master SB=Standby

P=Parked S=Slave

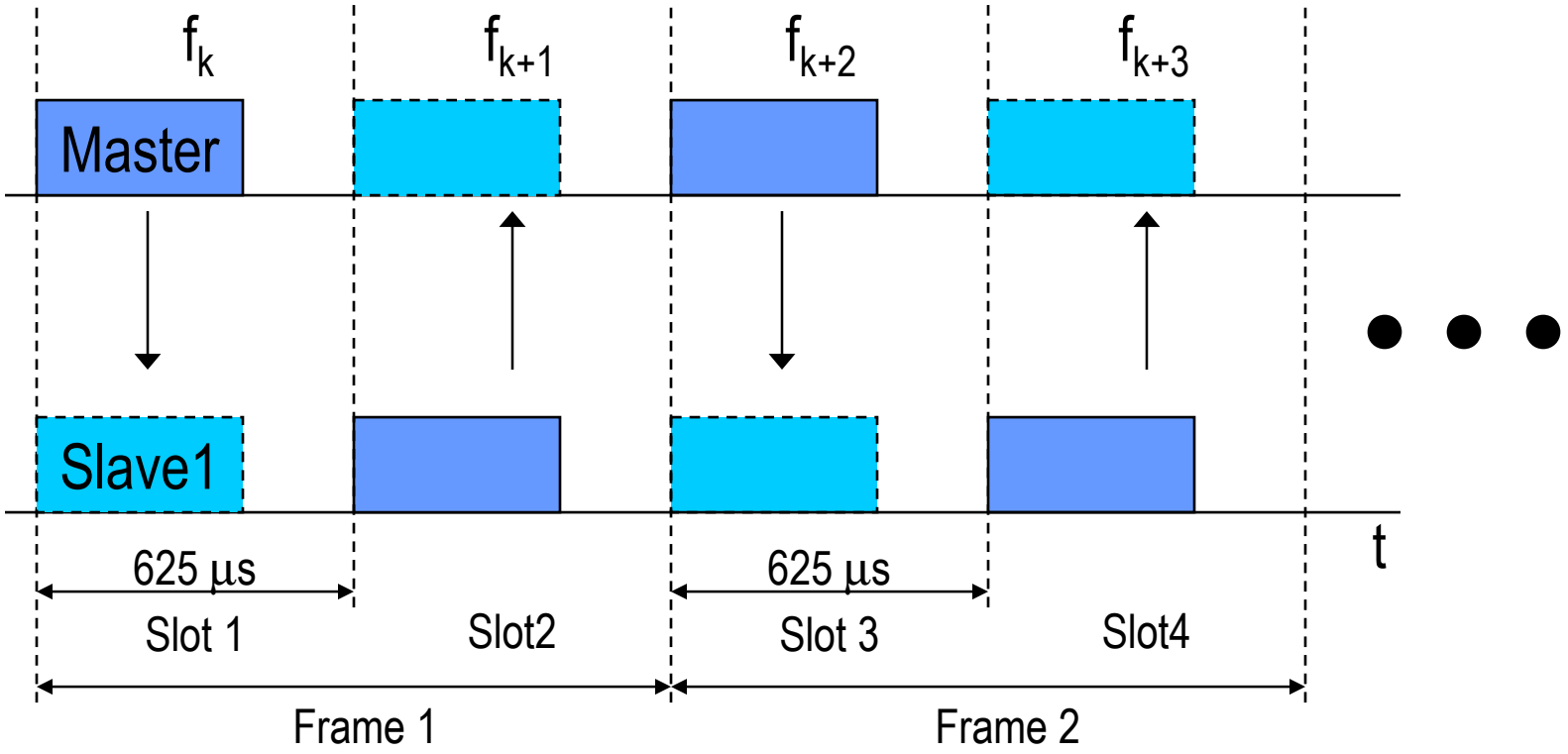
Radio & Baseband Specification

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

- **Operates in 2.4 GHz ISM:**
  - Divided into 79 hop frequencies: f = 2402+k MHz, k= 0,..78 (but 23 in Spain, France, Japan), spaced 1 MHz apart.
- **Restriction of ISM band for FH system:**
  - Signal bandwidth is limited to 1 MHz
  - Data rates is limited to 1 Mb/s per channel
- **GFSK:**
  - Binary ‘1’: sent as positive freq deviation from RF channel center freq
  - Binary ‘0’: sent as negative freq deviation from the channel center freq
- **Bluetooth radio is based on FHSS and TDD:**
  - In time domain, RF channel is divided into time slot of 625 micro secs on different frequency
- **Terminology:**
  - Frame = a complete transmit/receive cycle
  - Slot = a 625 microsecond segment within a frame

Frequency Hopping & Time Division Duplexing

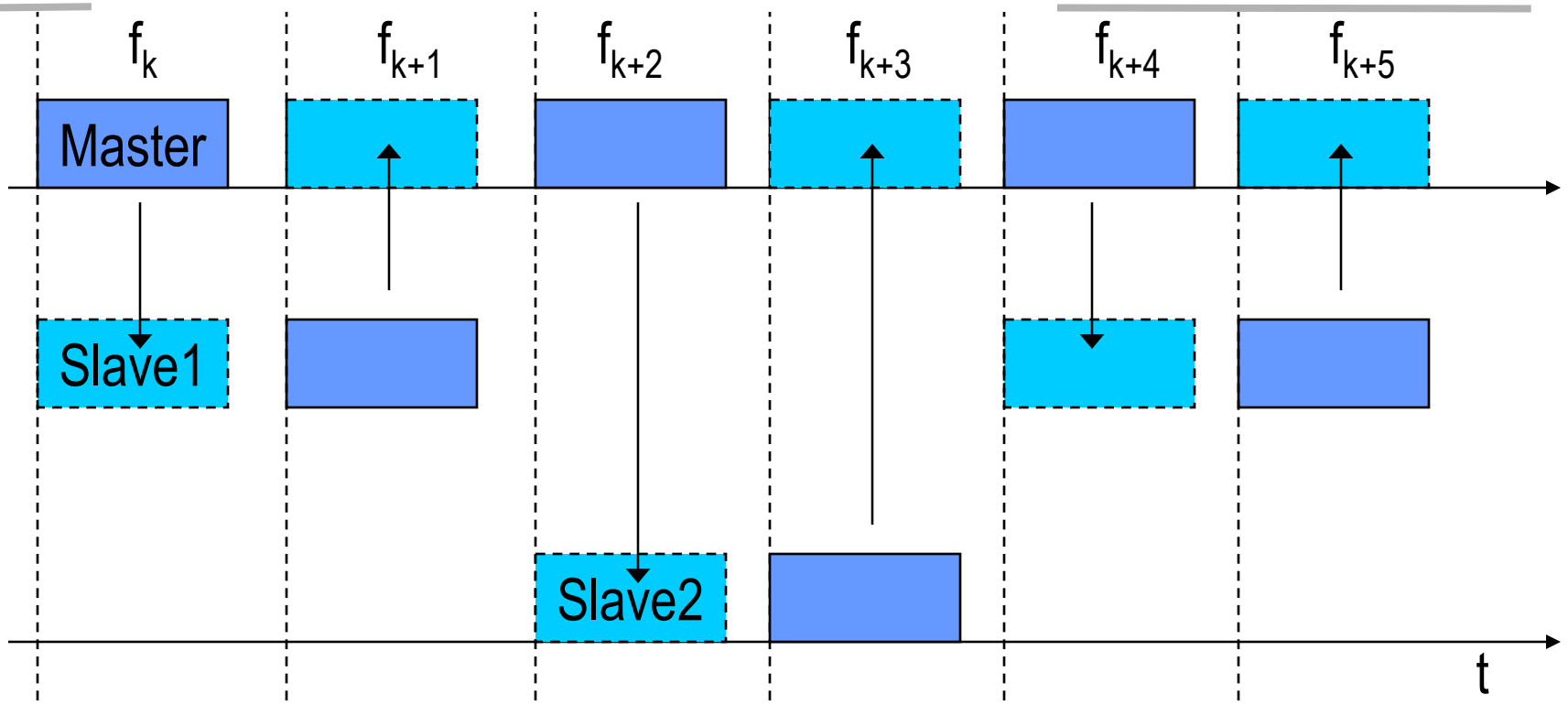
University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer



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

Multi-Slave Transmission

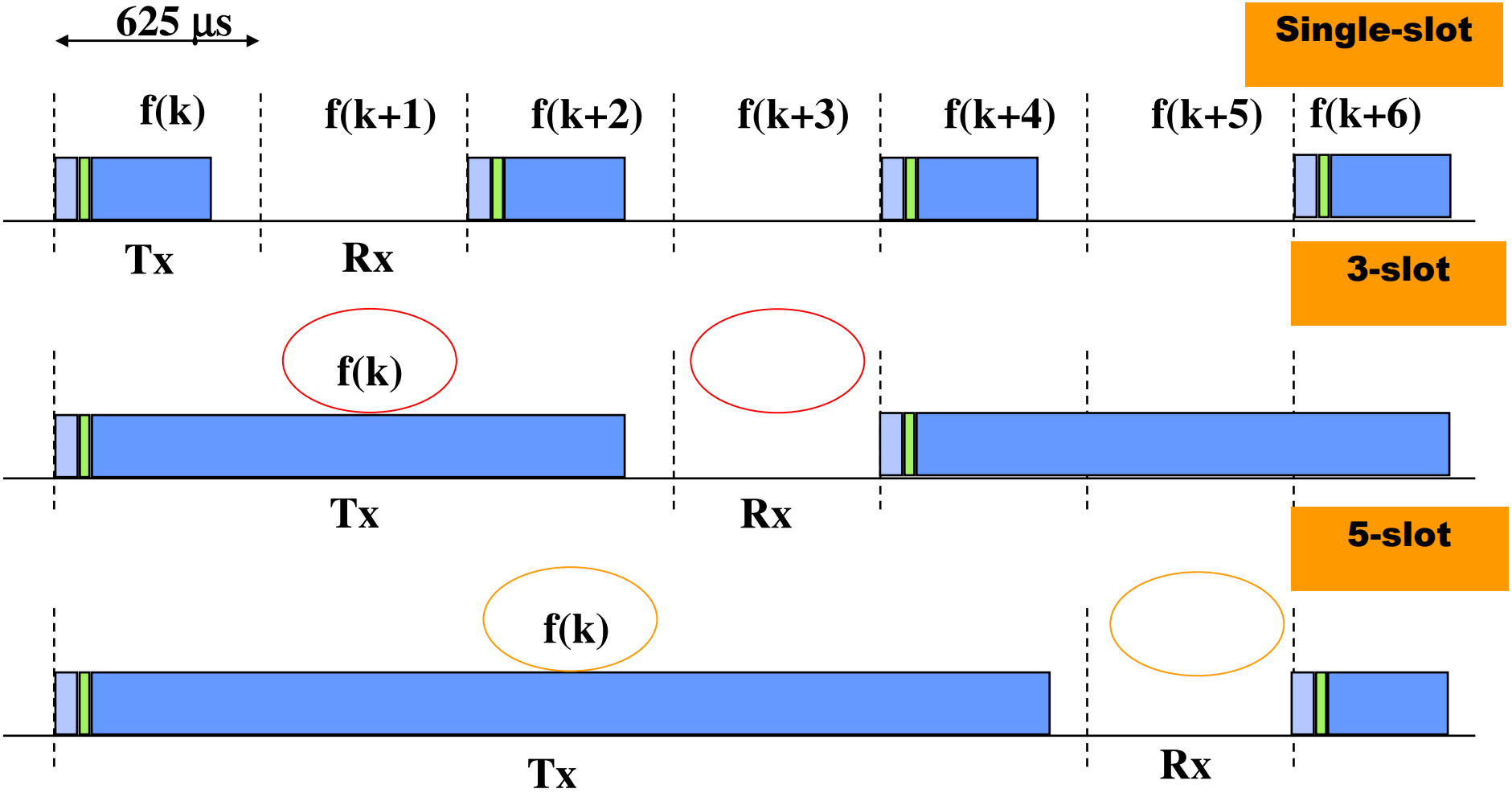
University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer



- The Bluetooth master interleaves traffic between multiple simultaneously active slaves.
- Each Master can support up to 7 simultaneously active slaves

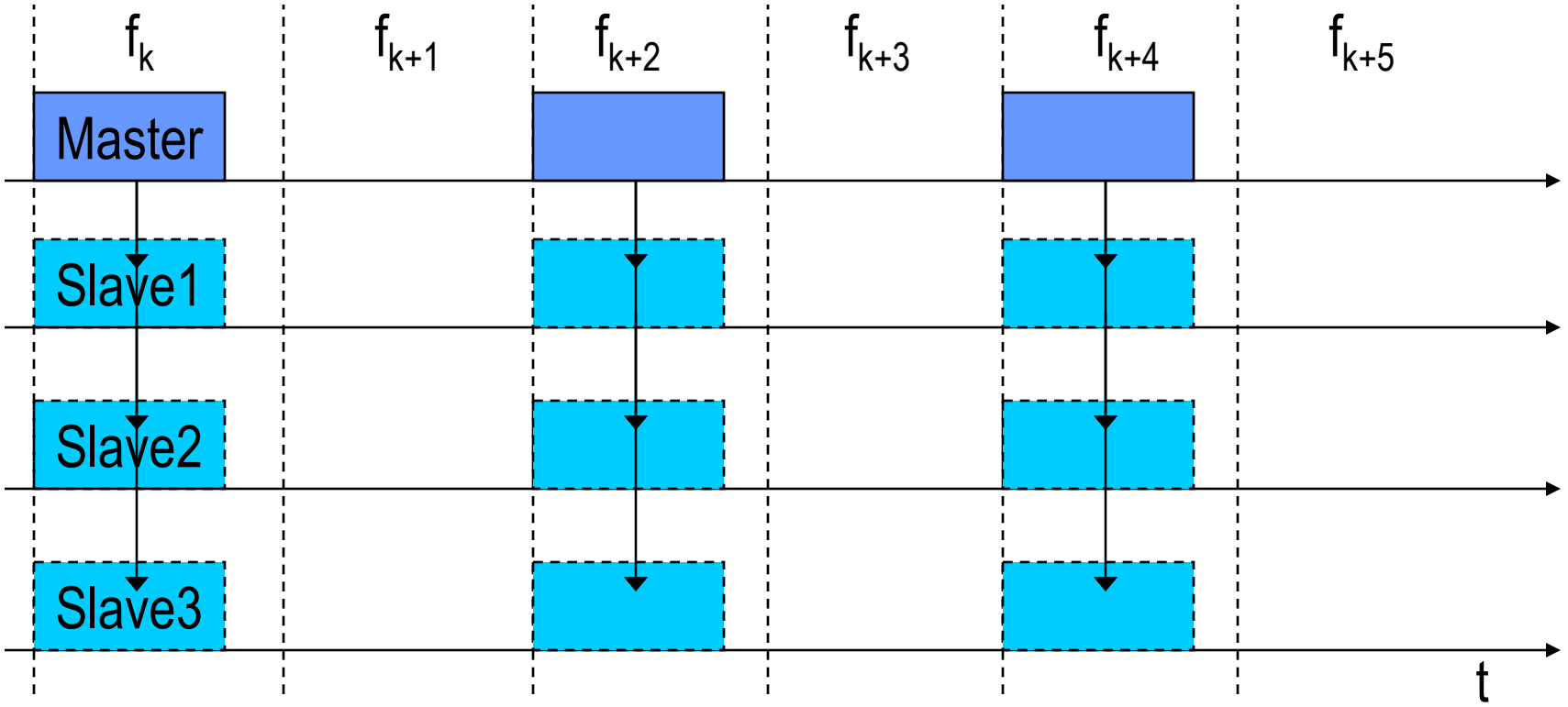
Multi-Slot Packets
⇒ Reduced Overhead

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer



Point to Multi-Point Transmission

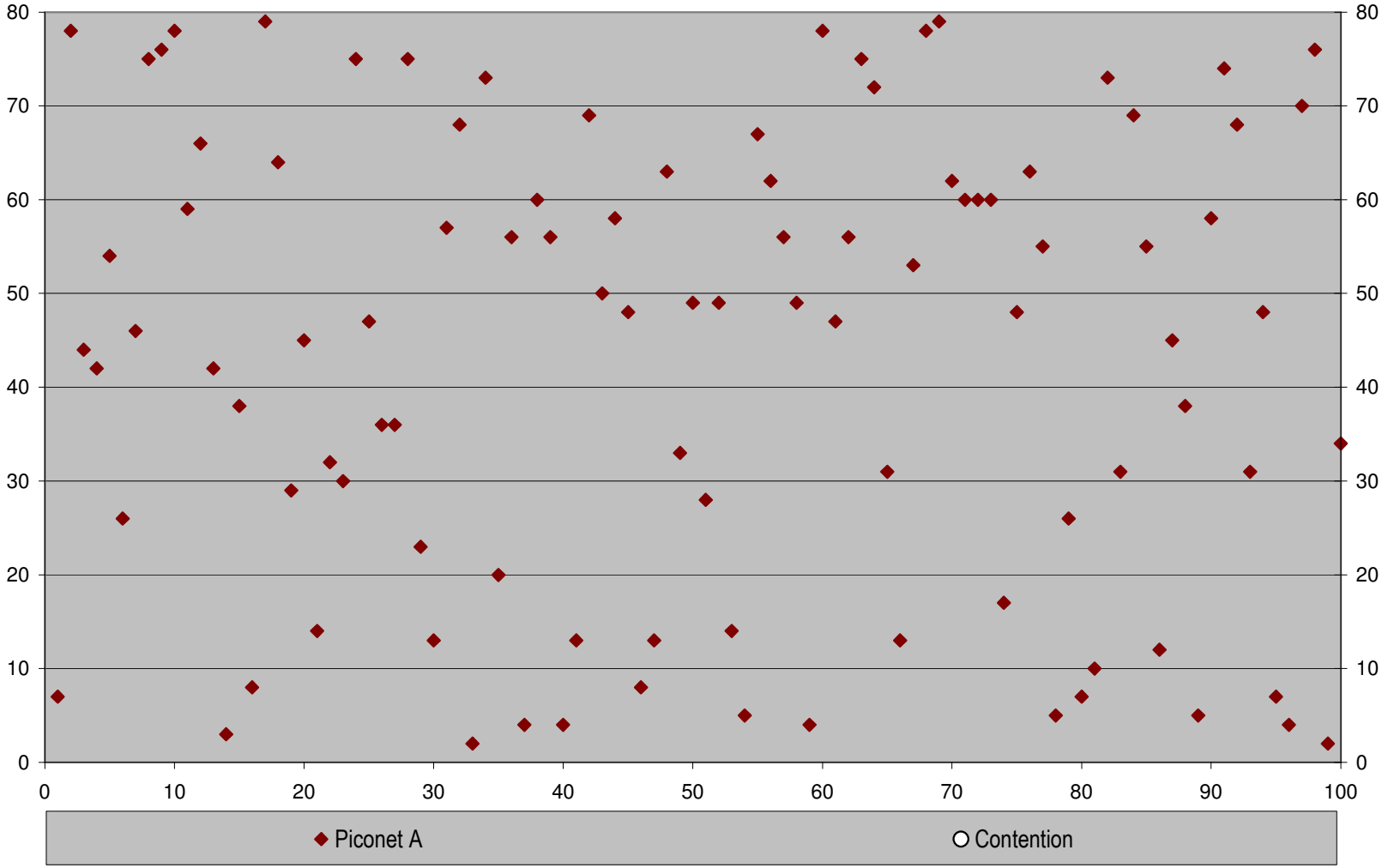
University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer



- The Bluetooth Master can also simultaneously transmit to all of its active Slaves at one time
- In such transmissions there can be no reverse traffic from the Slaves

FHSS in Piconet

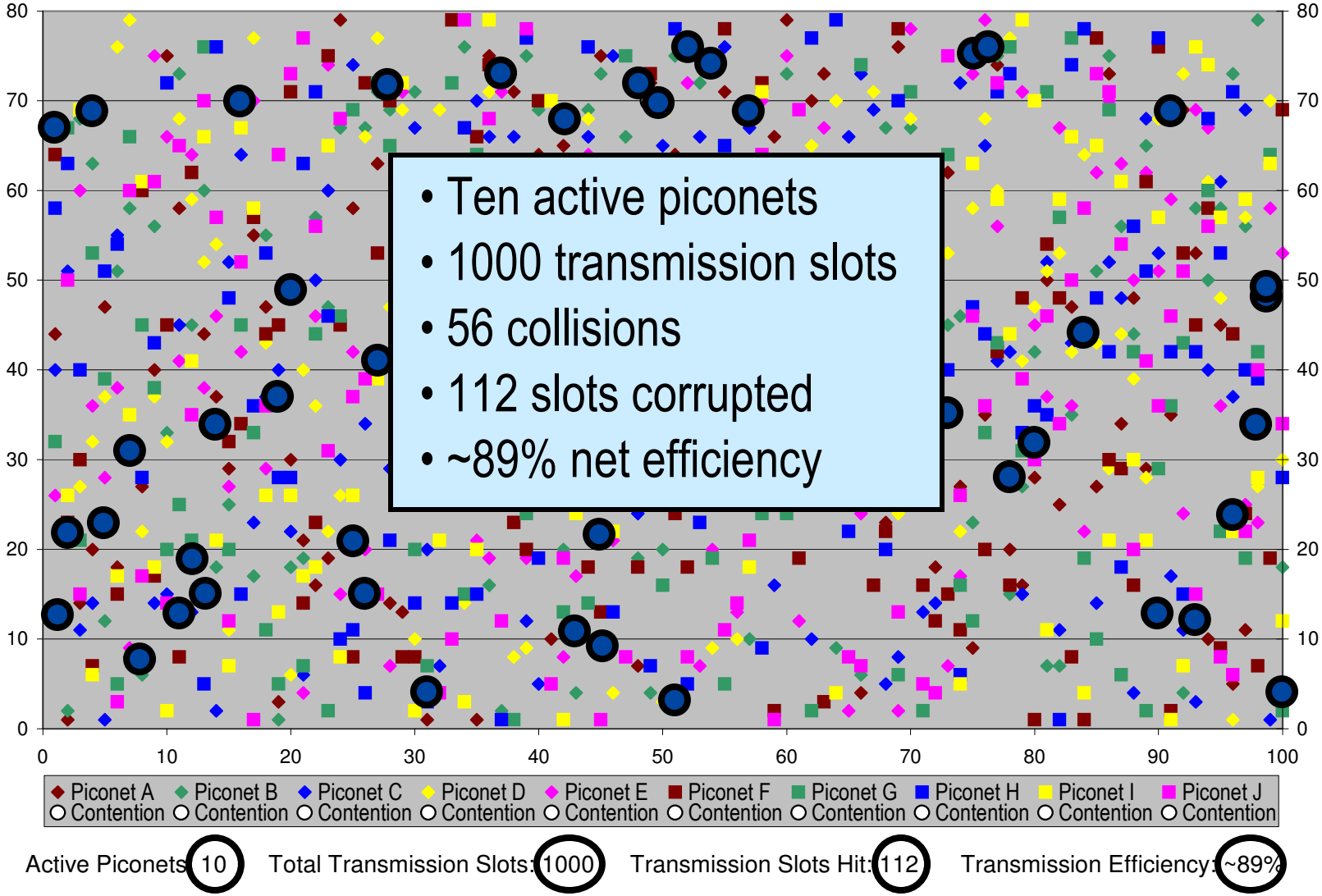
University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer



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

Bluetooth Piconets Degrade Gracefully with Density...

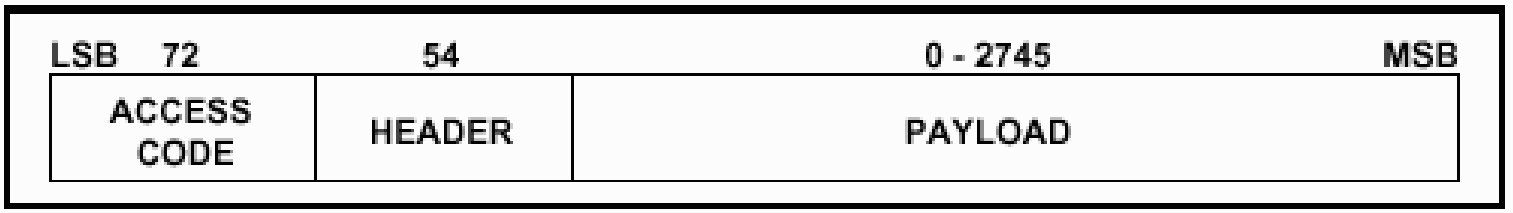
University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer



Baseband: Packets

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

- **Packet Format:**



- **Access Code: timing synchronization, offset compensation, paging and inquiry.**
  - Three types : Channel Access Code (CAC), Device Access Code (DAC) and Inquiry Access Code (IAC).
- **Packet Header:**
  - Target device address
  - Type code
  - information for packet acknowledgement, sequencing, flow control, CRC
- **Payload: voice field, data field or both.**

Baseband: Error Correction

University of Freiburg
Institute of Computer Science
Computer Networks and Telematics
Prof. Christian Schindelhauer

- **Fast ARQ is implemented**
  - To minimize complexity, overhead, and wasteful retransmission
  - Sender is notified of packet reception in Rx slot after Tx

Thank you

University of Freiburg
Computer Networks and Telematics
Prof. Christian Schindelhauer

Wireless Sensor Networks
Christian Schindelhauer
schindel@informatik.uni-freiburg.de

11th Lecture
29.11.2006