Token based Protocols

Token-Protocols

Token Passing:

Multiple Masters circulate a token.

Token Ring: physical ring (IEEE 802.5)
Token Bus: logical ring (IEEE 802.4)

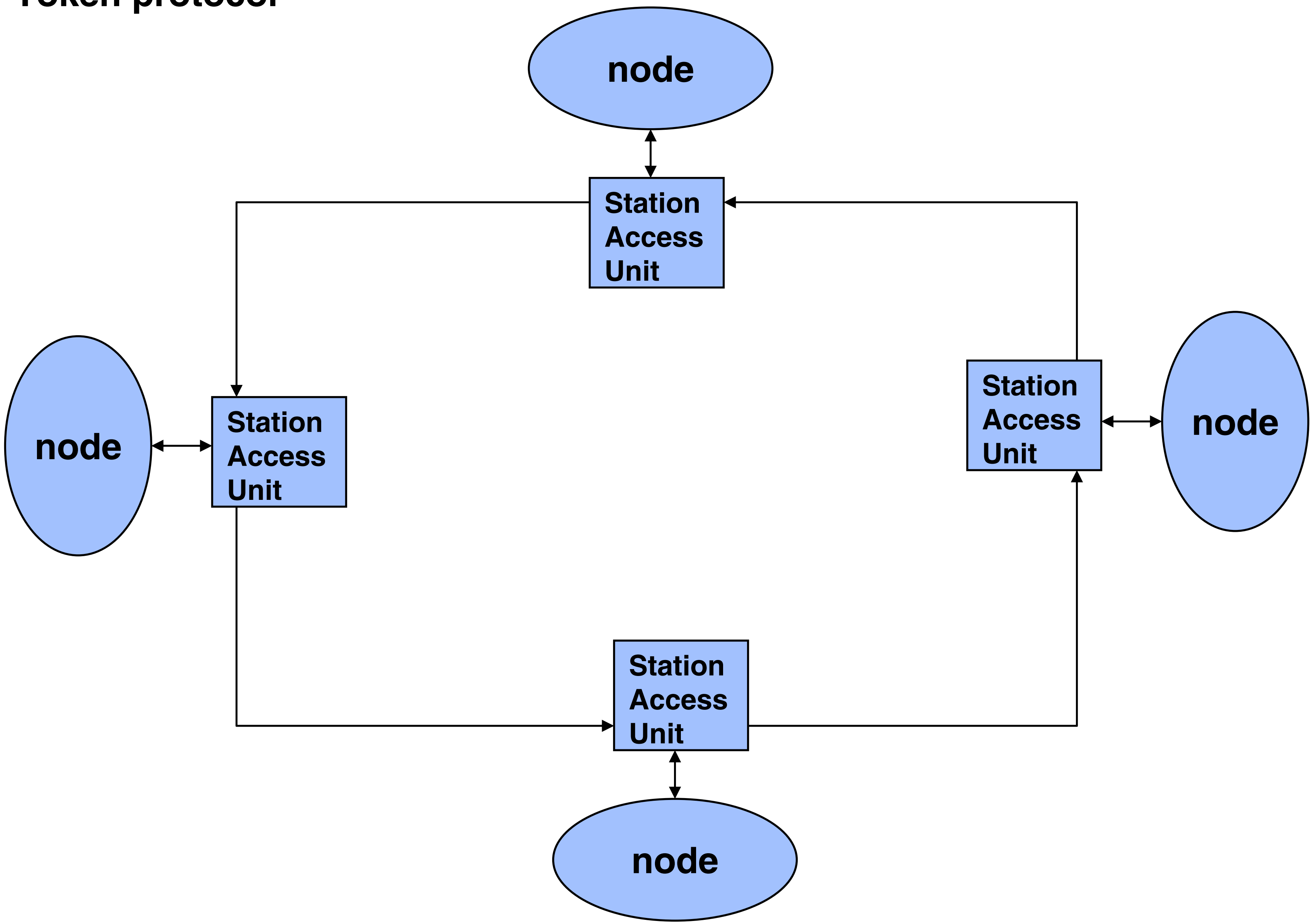
Delegated Token:

connection oriented: **Central busarbiter grants a token to a participant to send one or more messages.**

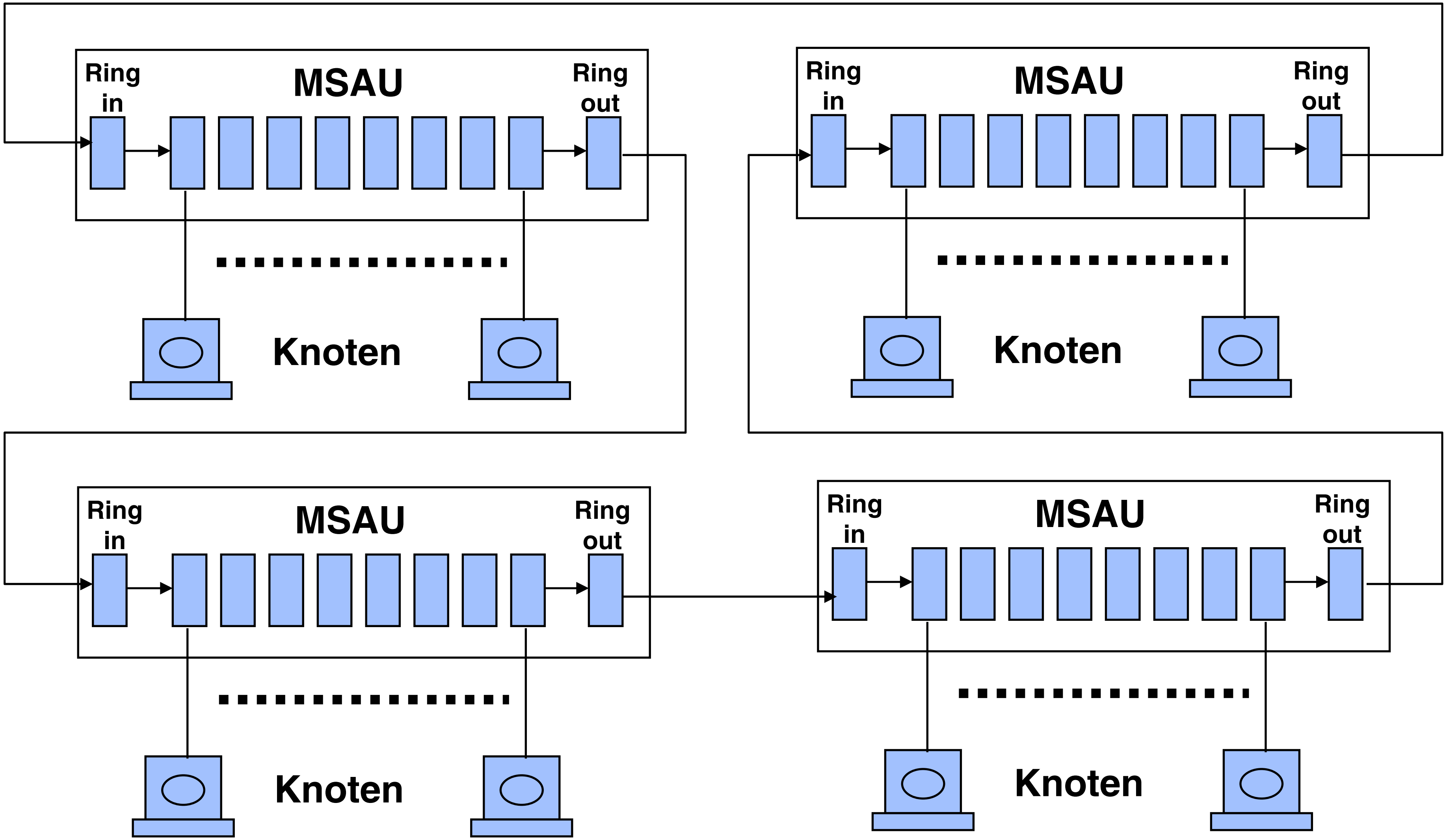
message oriented: **The central busarbiter requests a participant to send a message by sending the token to this participant. Centrally controlled message dissemination.**

Examples: Connection oriented: Profibus (Token Passing (logical Ring)
message oriented: FIP (Factory Instrumentation Protocol)

Token protocol

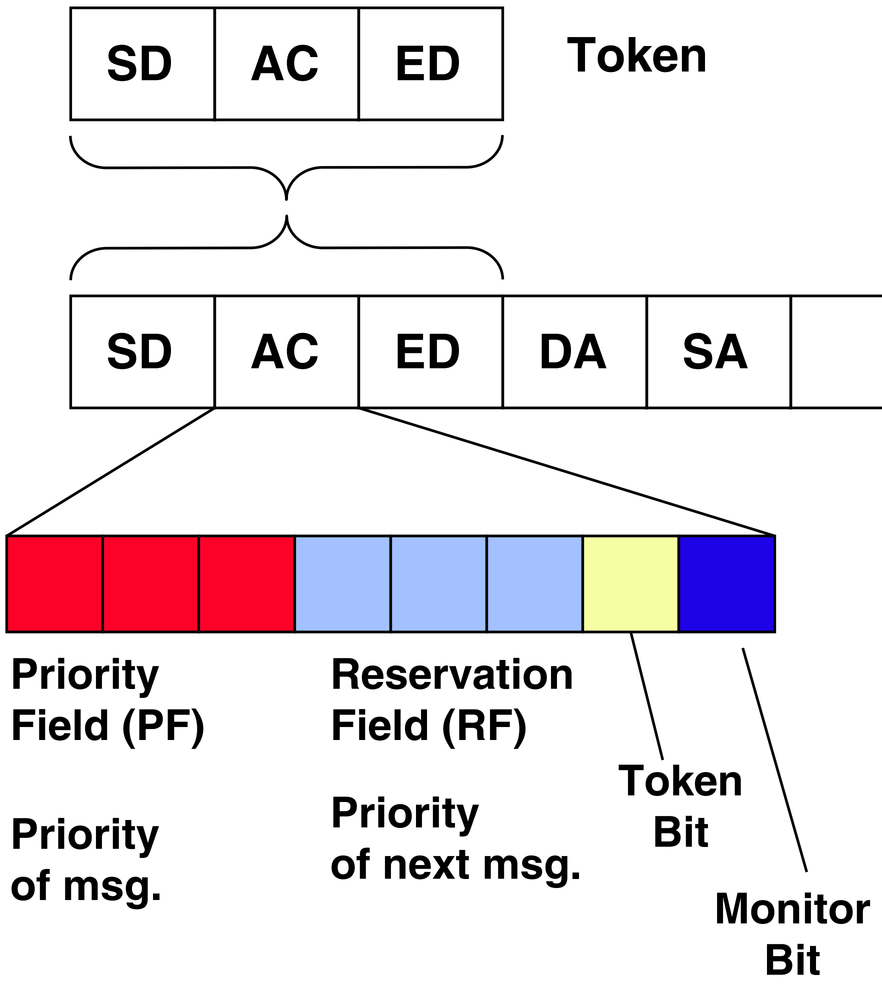


Token network topology



MSAU: Multi Station Access Unit

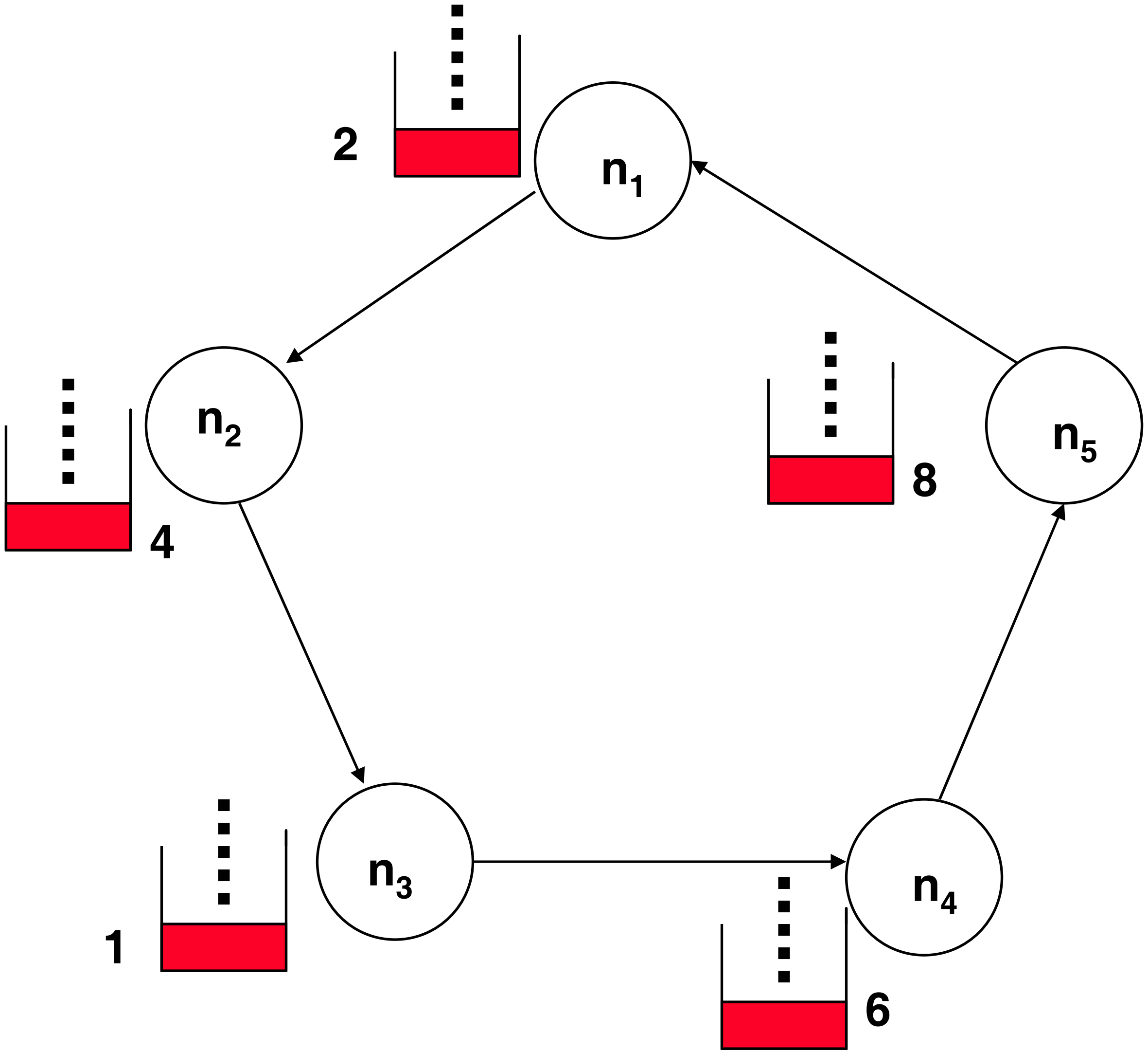
802.5 Token Ring Frame Format



SD: Start Delimiter
AC: Access Control
ED: Ending Delimiter
SA: Source Address
DA: Destination Address
FS: Frame Status

- FS = 00: Station not available
- FS = 10: Frame not delivered although station was available
- FS = 11: successfully received

Priority based reservation of messages



Round n:
node n_4 sends packet with priority x. RF is RF=6.
- **n_1 changes RF = 2**
- **n_2 and n_5 don't change**
- **n_3 changes RF into RF = 1**

Round n+1:
- **n_4 generates Token with PF = 1 and sends token on the ring.**
- **node node except n_3 is able to use the token because lower priorities.**
- **n_3 detectsa message with the respective priority is in its local send queue and appends this msg to the token. Node n_3 also resets the token to the original value (=2).**

Token Ring/IEEE 802.5

Priority System

Token Ring networks use a sophisticated priority system that permits certain user-designated, high-priority stations to use the network more frequently. Token Ring frames have two fields that control priority: the *priority* field and the *reservation* field.

Only stations with a priority equal to or higher than the priority value contained in a token can seize that token. After the token is seized and changed to an information frame, only stations with a priority value higher than that of the transmitting station can reserve the token for the next pass around the network.

When the next token is generated, it includes the higher priority of the reserving station. Stations that raise a token's priority level must reinstate the previous priority after their transmission is complete.

The “Timed Token Protocol”

Scheduling analysis

Key parameter is $W_T = (n-1)\, D_B + T_{prop}$

W_T = Walktime: time for a single round
n = Number of stations in the ring
D_B = Station Delay: message delay in a station
T_{prop} = message transmision time on the ring

- **messages cannot be interrupted**
- **because of the message transmission time, the priority in the RF-field may be outdated**

Timed Token Protocol

Properties:

- guaranteed transmission of cyclic hard real-time messages (HRT)
- **- The cycle, in which a station may send, is restricted**
- **- the amount of information (bandwidth) is known and guaranteed**

→ **Synchronous messages**

- transmission of SRT- or NRT-messages (soft/non real-time) may not extend the cycle

→ **Asynchronous messages**

Timed Token Protokoll

What is needed to guarantee the message transmission of HRT-msg ?

1. How long is the time interval T, that a message (at most) has to wait to be sent?

Determine the value T: Each node sends its maximum T_i . The lowest T_i determines the overall requirement $T = \min(T_i)$

2. What is the amount of information which nodes can send in this interval?

Target Token Rotation Time (TTRT)

TTRT is the time that a token needs for complete cycle.

TTRT is composed of:

- **Delays on the medium for messages**
- **Token transmission time**
- **time to fetch the token from the net**
- **latency of the network interface**

} **Overhead**

- **time to transmit a message**

} **utilization**

Assumption: Overhead is small an can be neglected

Target Token Rotationszeit (TTRT)

TTRT is NO worst-case Assumption, but a system dependent assumption that includes synchronous and asynchronous messages and e.g. is based on average rotation times. Therefore, T=TTRT cannot be guaranteed.

It can be shown that the upper bound T= 2 TTRT can be guaranteed.

Trick: If a message must be sent every T = min (T_i) time units

we set: TTRT = T/2.

Prolog for the Timed Token Protocol

1. phase: Determine T

2. phase: Determine load for synchronous messages

Estimating the load:

t_p = TTRT - O : time for the payload in a cycle.

B: Amount of information Bit/sec (bandwidth of the network)

Each Station is allowed to send a certain share f_i of the overall bandwidth in every cycle ($\Sigma f_i = 1$).

Quota of the synchronous messages of station i: $Q = f_i B t_p$

How to guarantee T=2TTRT in spite of asynchronous traffic?

Timed Token Protocol

The sum of synchronous msg.

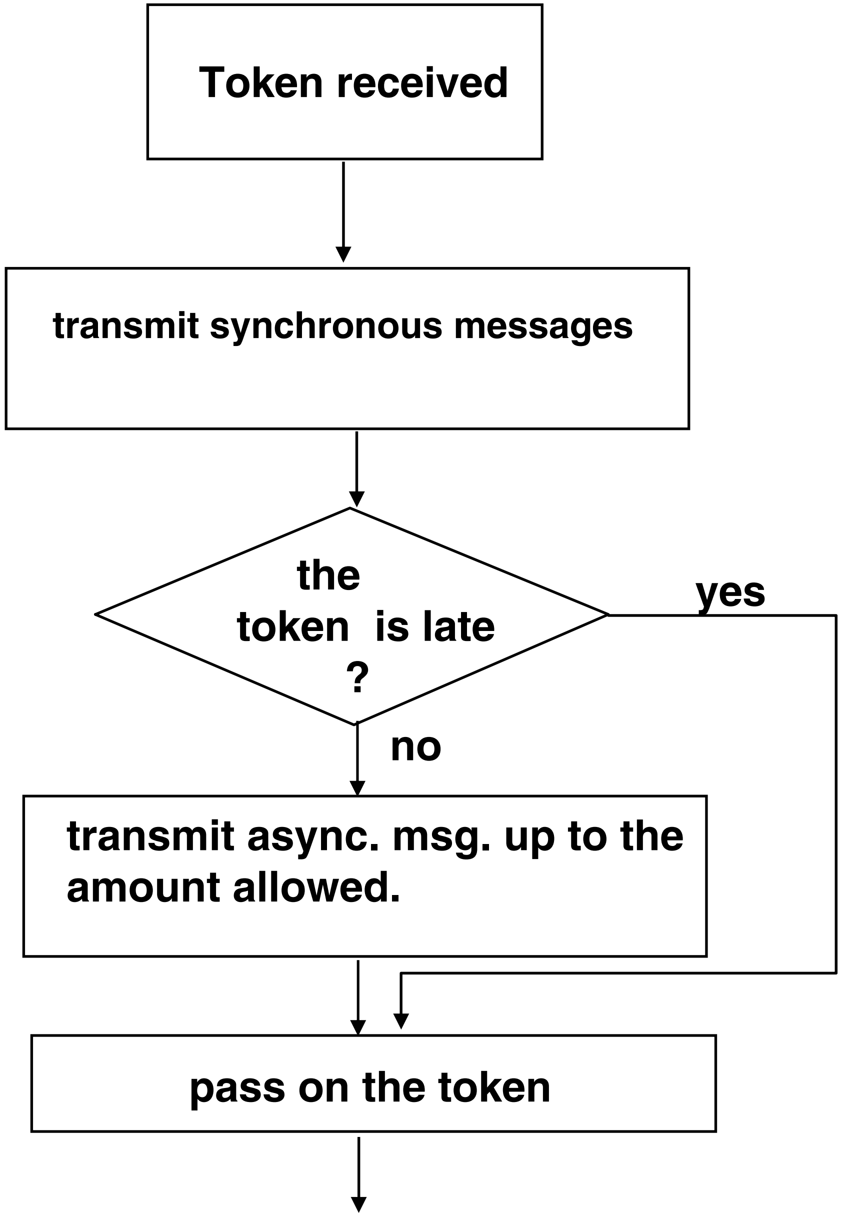
$\sum f_i t_p <= TTRT$ $\sum f_i <= TTRT$

bounded by ($\sum f_i <=1$!).

On token arrival, the station checks how much time passed since the last vist.

Def.:
the token is:

***early,* iff: cycle time <= TTRT**
***late*, iff: cycle time > TTRT**



Analysis of the Timed Token Protocol

Theorem:

The maximum time between 2 visits on the same station is no more than 2 TTRT in a fault-free system

proof (idea):

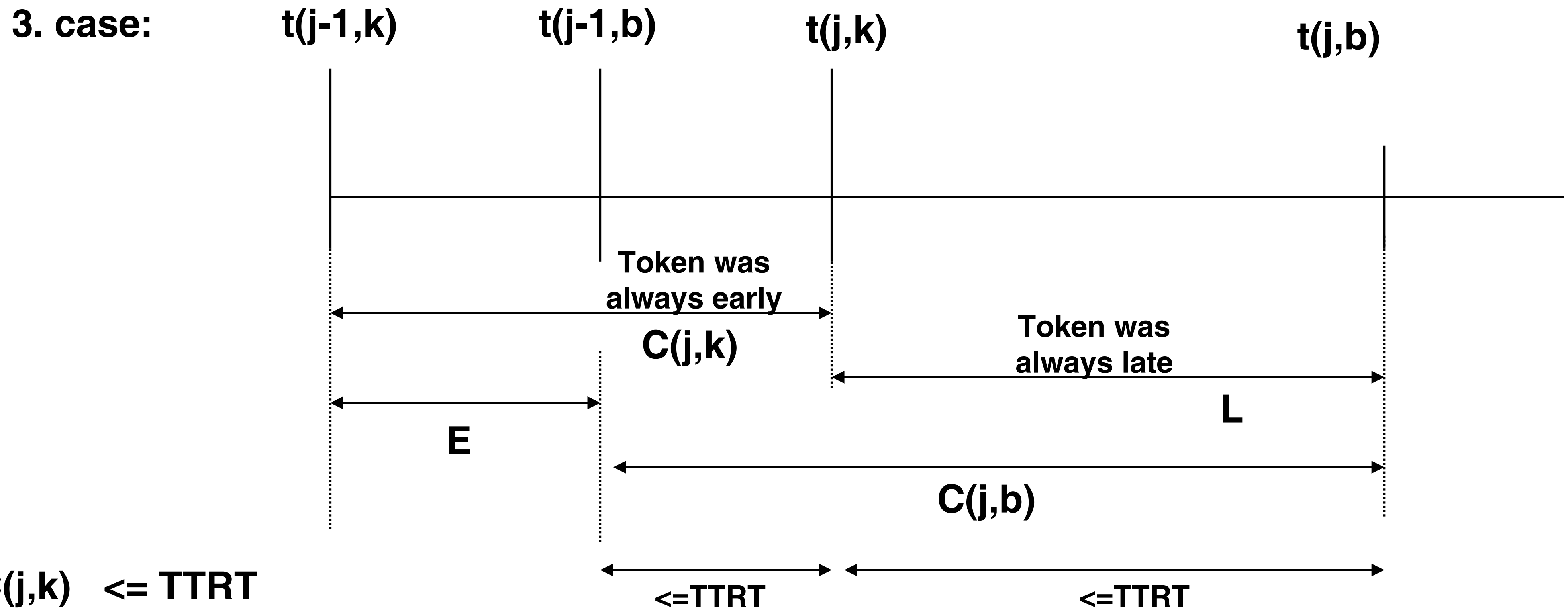
1. case: the token is always early. According to the definition of early, no more time than TTRT < 2TTRT passed since the last visit.

2. case: The token is always late. Then the station is allowed to send synchronous messages only.The sum of all quotas of synchronous messages is bounded by

$$\sum f_i t_p <= TTRT \sum f_i <= TTRT \text{ with } (\sum f_i <=1).$$

Therefore, the assumption holds.

Analysis of the Timed Token Protocol



$C(j,k) \le TTRT$

$C(j,b) = C(j,k) - E + L$

$\le TTRT - E + \sum_{y,x = j,k \ldots j,b} S(x,y)$

$\le TTRT + \sum_{y,x = j,k \ldots j,b} S(x,y)$

$\le TTRT + TTRT = 2\ TTRT$

Because the token was always late during L, only synchronous messages are sent.

C(j,k) : j-th token-cycle time for node k; Σ x,y= j,k....a,b S(x,y) are all synchronous messages transmitted during L.

Predictability of various Networks*

Worst Case Times of Inaccessibility*	t_{inacc} (ms)	
ISO 8002/4 Token Bus (5 Mbps)	139.99	Token-based Protocols
ISO 8002/5 Token Ring (4 Mbps)	28278.30	
ISO 9314 FDDI (100 Mbps)	9457.33	
Profibus (500 kbps)	74.80	
CSMA/CD	unbounded	CSMA Protocols
CSMA/CA	stochastic	
CAN-Bus (1Mbps)	2.48	

The worst-case-delay of the Timed-Token-Protocol is 2•TTRT (Target Token Rotating Time)**

* P. Verissimo, J. Ruffino, L. Ming:" How hard is hard real-time communication on field-busses?"

Controlled Access:

Master/Slave

- all control information in one place
- maximum of control
- easy to change

- Single point of failure
- More communication requirements
- Central bottleneck

Global Time

- Easy temporal co-ordination
- Minimal communication overhead

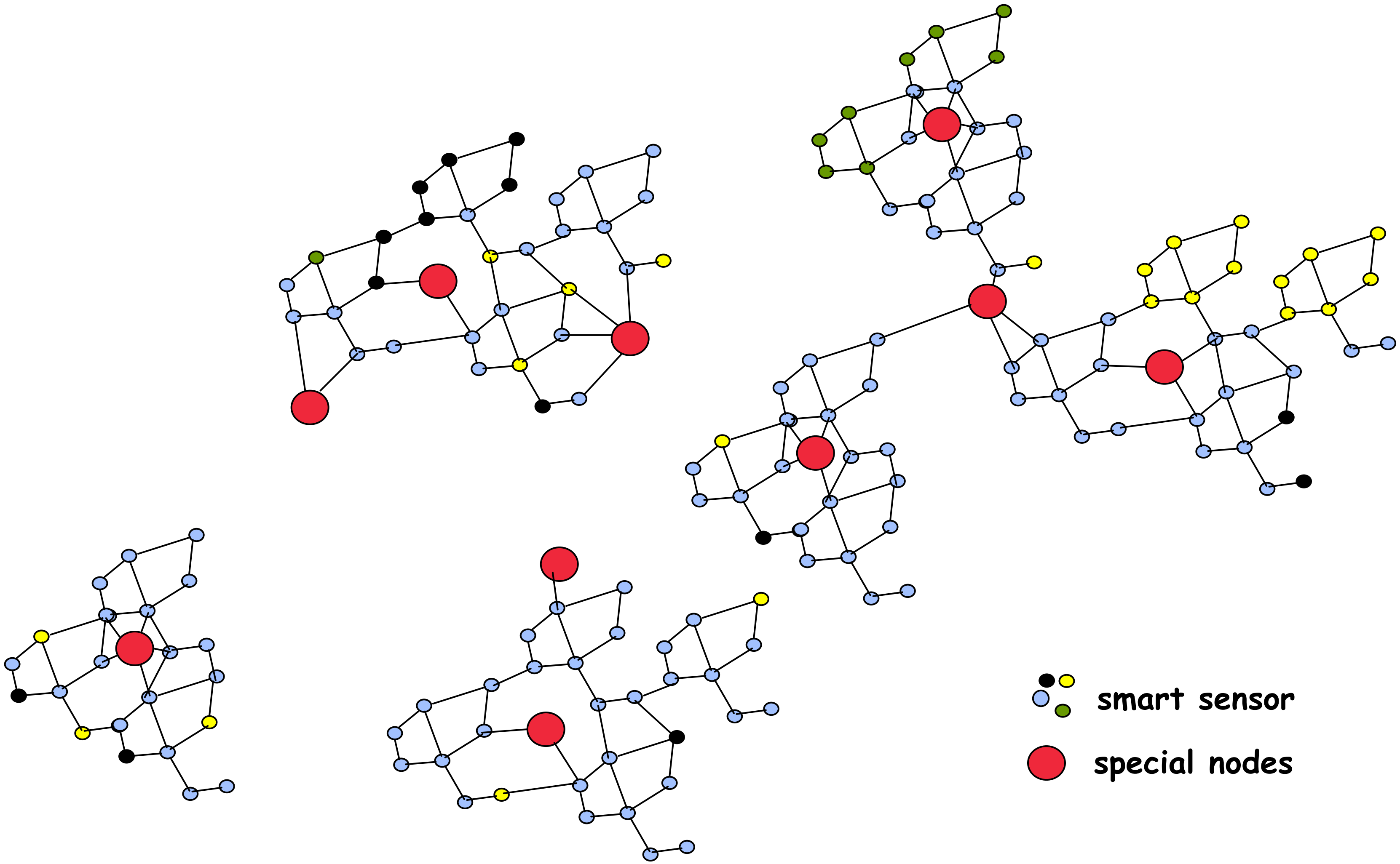
- Global knowledge of the calendar
- All nodes have to conform to global time
- Only critical messages

Token-based

- Decentralized mechanism
- Integration of critical and non-critical messages

- Latency of messages
- Long recovery time

Sensornets for a wired physical world



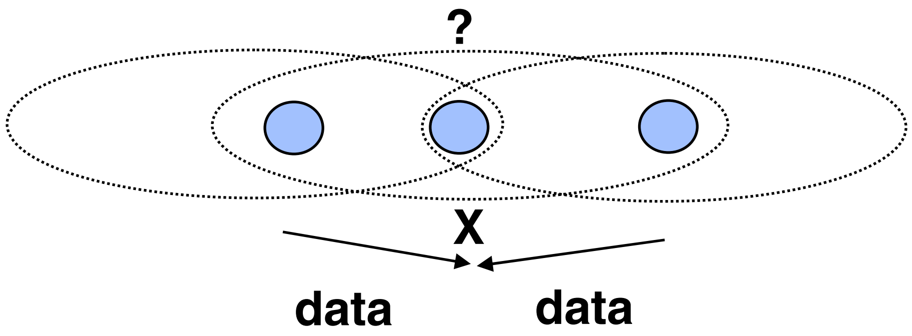
MAC-principles

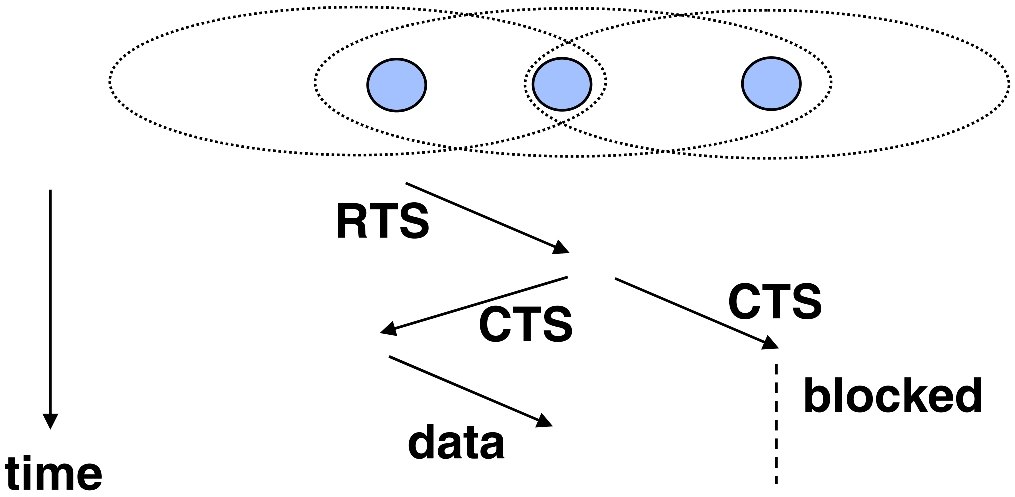
	trigger to send	Start time	channels
(simple) Aloha	data availability	arbitrary	1
Slotted Aloha	time slots	start of a time slot	1
MACA	RTS/CTS	dyn. reservation	1
MACAW	MACA + Acknowledge	same as MACA	1
CSMA	medium free	arbitrary	1
CSMA/CA	medium free	after waiting time or dyn. reserv.	1
TDMA	acc.schedule	preplanned	1
FDMA	multiple frquencies	arbitrary	m
CDMA	orthogonal codes	arbitrary	m

Problems

Multiple Access with Collision Avoidance (MACA)

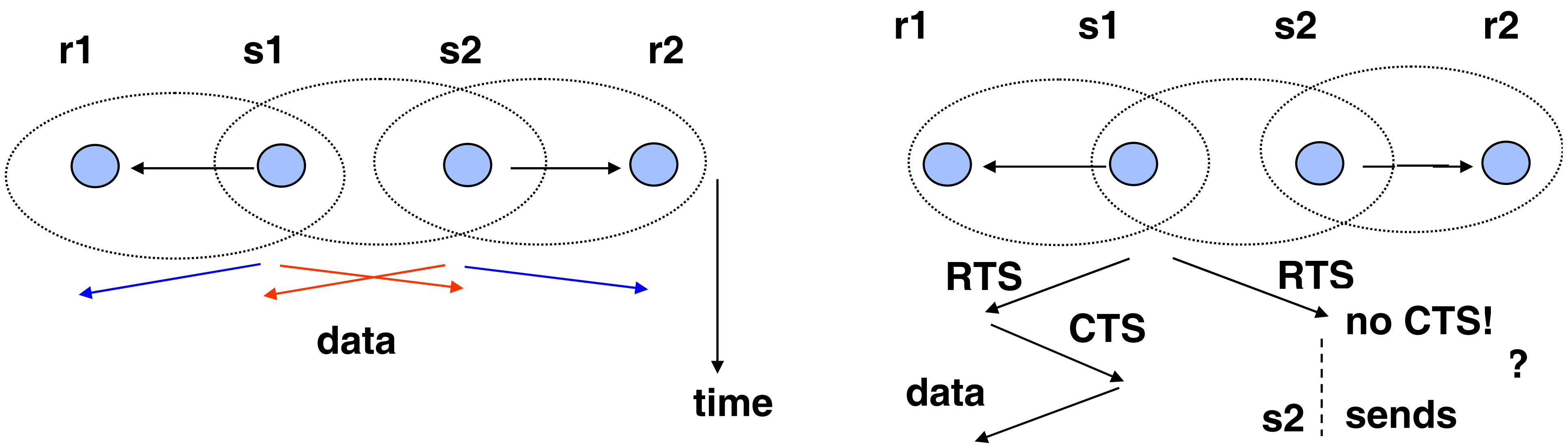
Hidden Terminal Problem





More problems

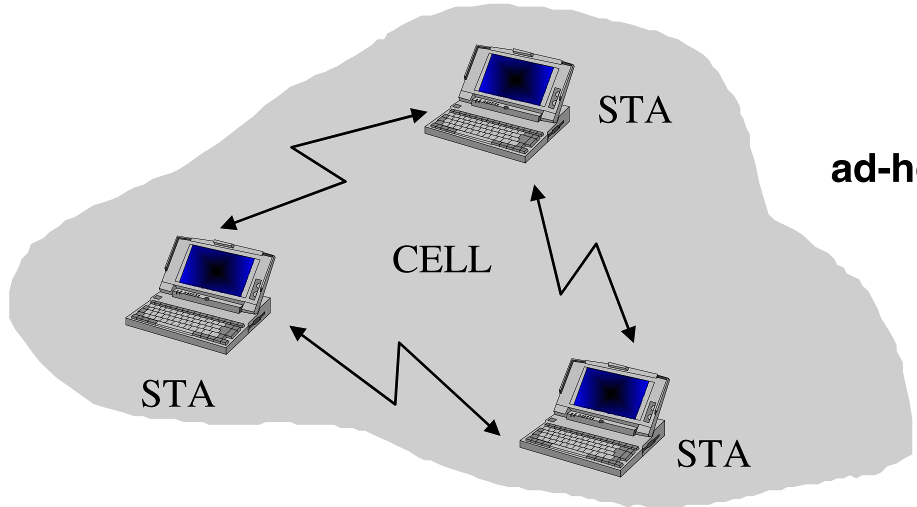
Exposed Terminal Problem



RTS/CTS to improve throughput

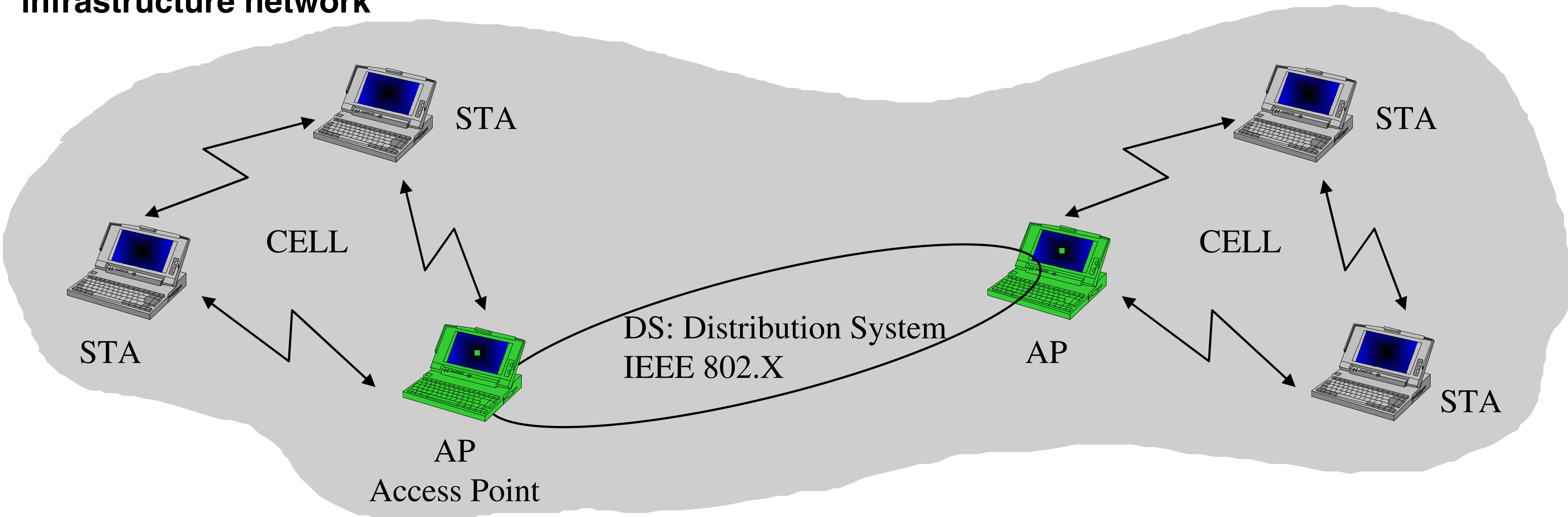
IEEE 802.11

Network Types



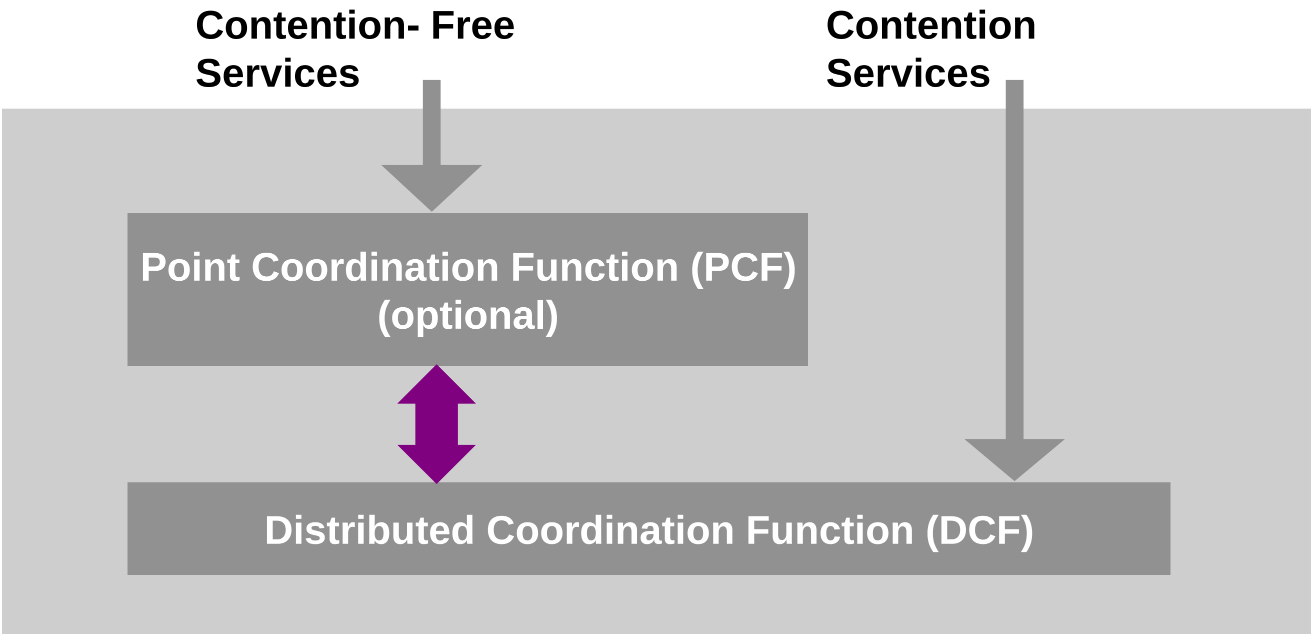
ad-hoc network

infrastructure network

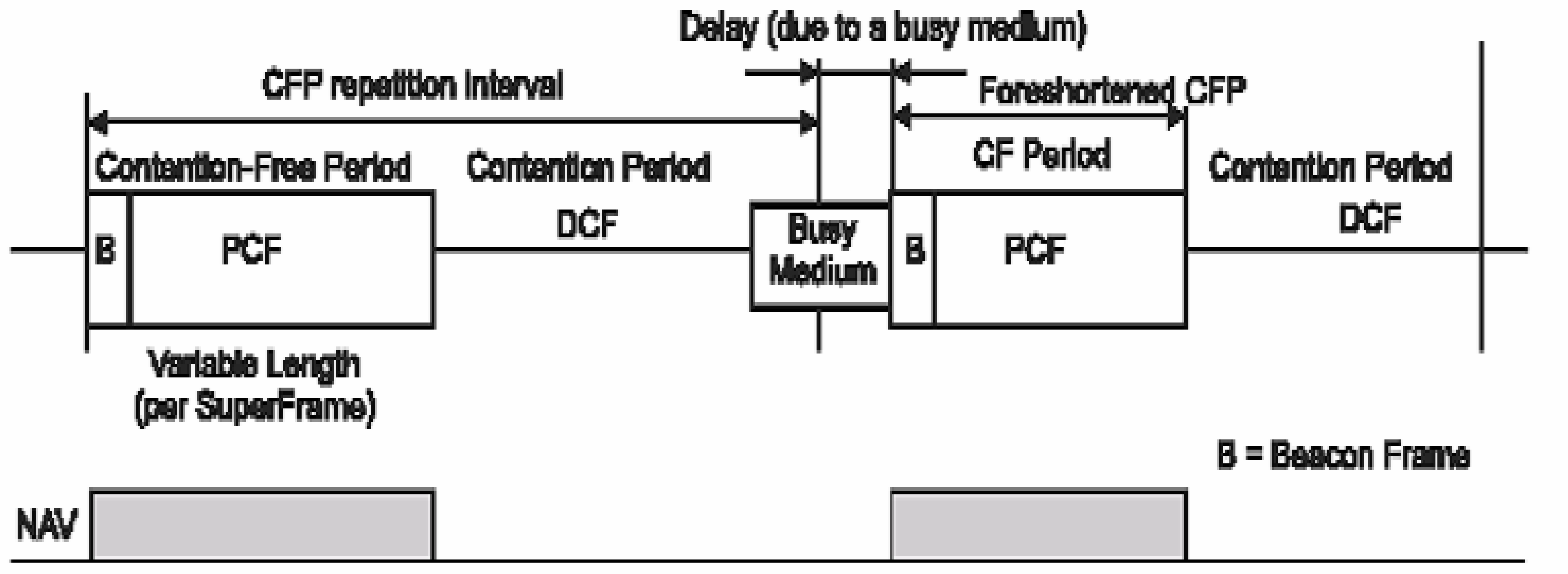


IEEE 802.11 MAC Layer

MAC Architektur:



Alternation of PCF and DCF

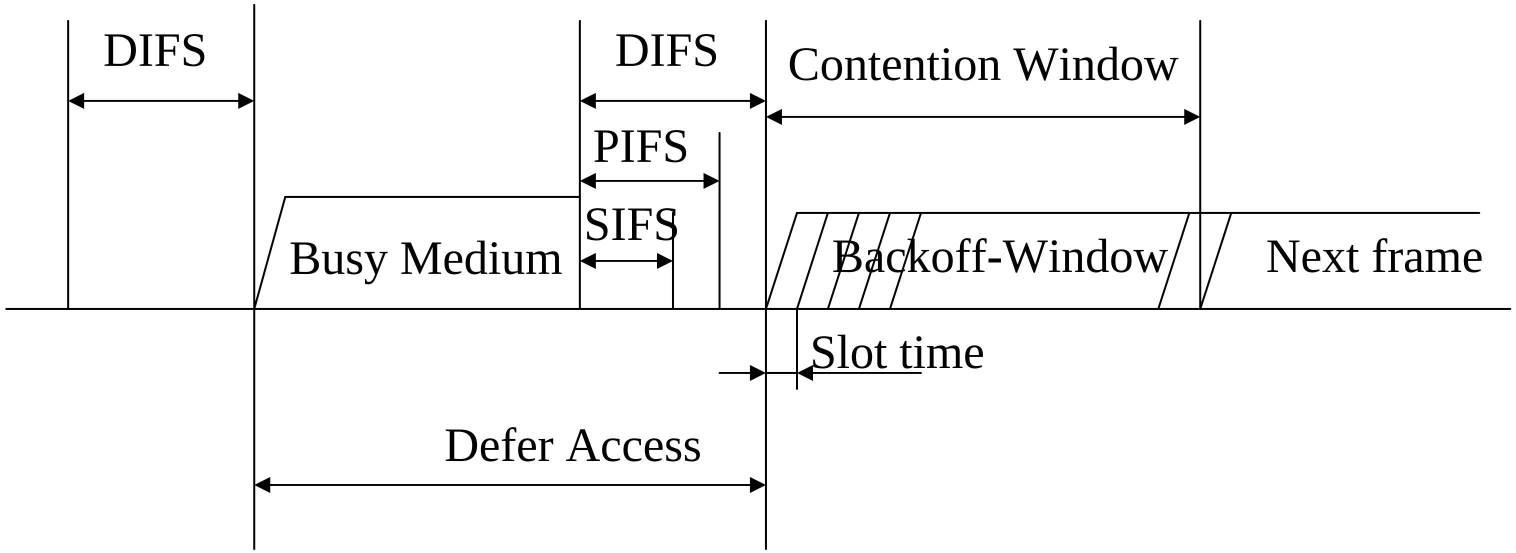


Distributed Coordination Function (DCF)

- CSMA/CA Protocol
- Collision Avoidance by random backoff procedure (p-persistent)
- All Frames are acknowledged, lost Frames are resend
- Priority Access by Interframe Space (IFS)

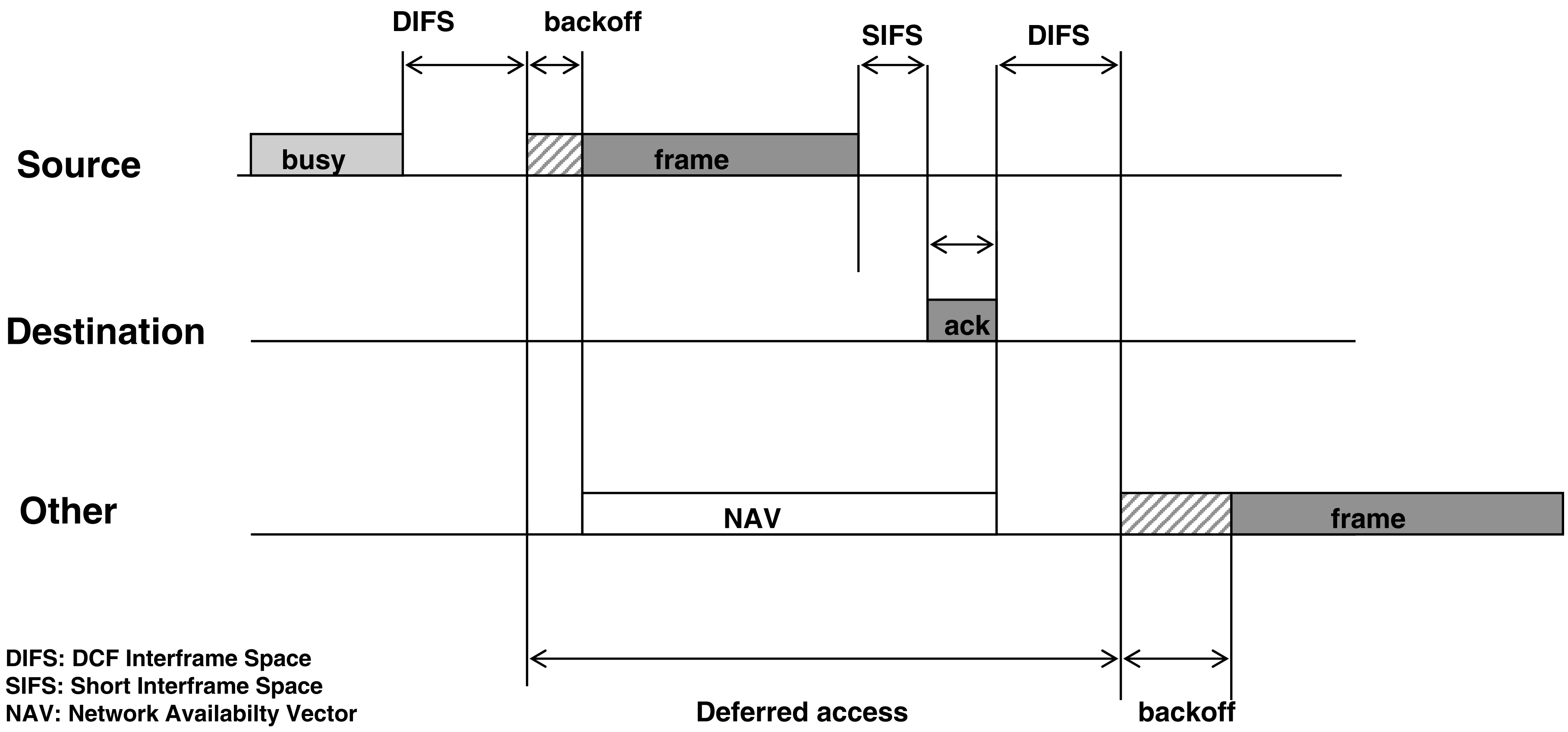
=> fair arbitration but no real-time support

Relationship of different IFSs in 802.11



DIFS: DCF Interframe Space
PIFS: PCF Interframe Space
SIFS: Short Interframe Space

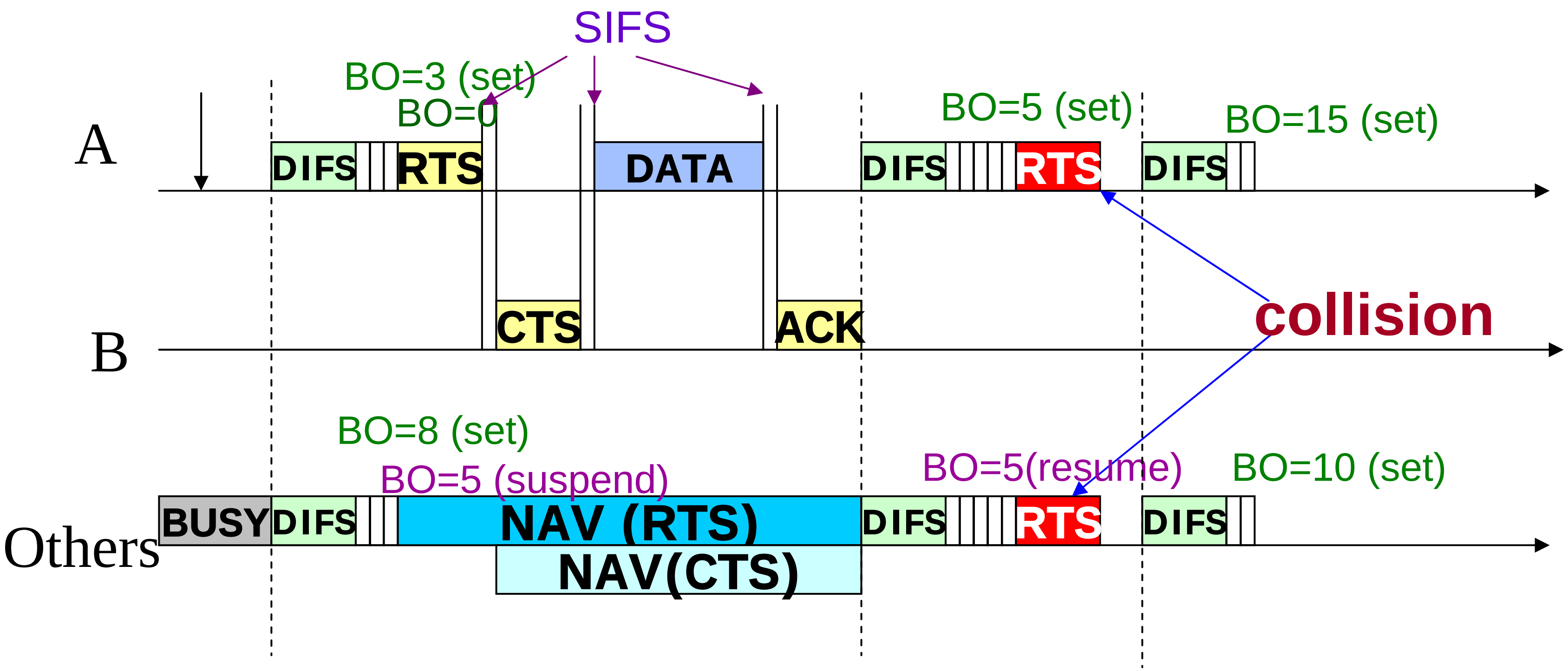
Basic DCF transmission protocol



DIFS: DCF Interframe Space
SIFS: Short Interframe Space
NAV: Network Availabilty Vector

Properties: Point-to-point, every frame is acknowledged

Example of 802.11 RTS/CTS/DATA/ACK Scheme



BO: backoff

Key parameters for wireless networks

	EasyRadio	RFMonolitics TR 1001	ChipCon CC1000	Lucent WLAN PC "Silver"
Frequency	868 MHz	868 MHz	868 MHz	2,4 GHz
Bit rate (Kbps)	19	115,2	76,8	11.000
Energy consumption				
send (mA)	17	12,0	25,4	284,0
receive (mA)	8	3,8	11,8	190,0
standby(µA)	--	0,7	30,0	10.000,0
switching time (µs)				
standby-transmit		16	2000	
receive-transmit		12	270	
standby-receive		518	2000	
transmit-receive		12	250	
transmit-standby		10		
receive-standby		10		

Sources of increased energy consumption:

active wait:	**If a node does not know when to expect a message, it must always remain in receive state.**
overhearing:	**A node receives a message for which it is not the destination. Better: switch off the node during this time.**
collisions:	**Energy which is used by sending a message during a collision is lost. The respective packet has to be resent completely. Collisions cannot be detected during sending.**
protocol overhead:	**Every additional measure like RTS/CTS or an acknowledge scheme increase the protocol overhead.**
Dynamic behaviour:	**Unbalanced load increases the probability of collisions (Thrashing).**

Biggest Problem:

idle listening

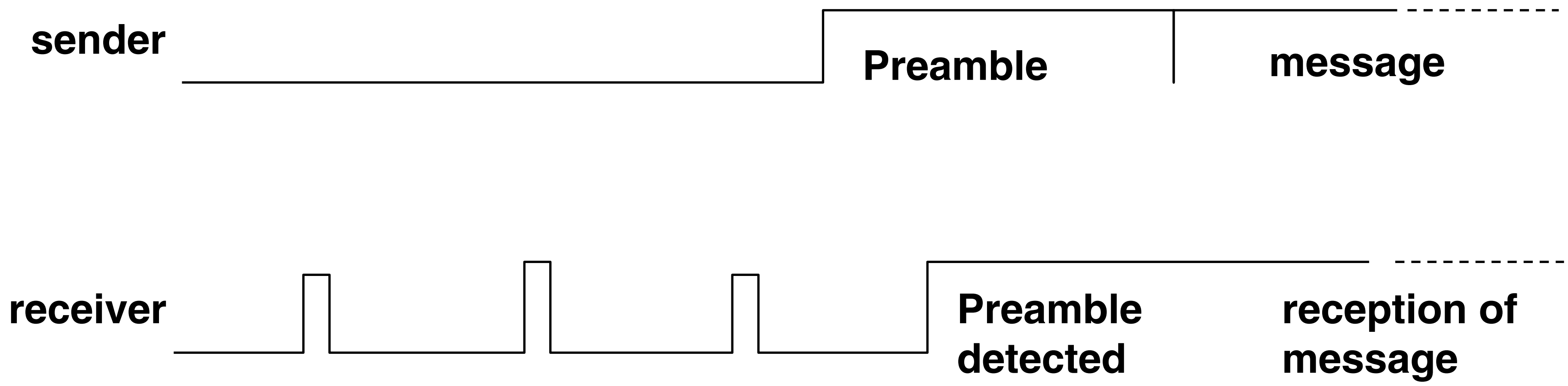
Energy efficient protocols try to minimize the time of active listening!

Approches:

- **Scheduling (TDMA)**
- **activation channel (narrow band additional channel)**
- **Preamble**
- **Adaptive schemes**

Variations: Low Power Listening

1.)



2.) Sender knows when the receiver is ready. Temporal coordination!

J. Hill, D. Culler: MICA: A wireless platform for deeply embedded networks. IEEE Micro 22(6), Nov. 2002

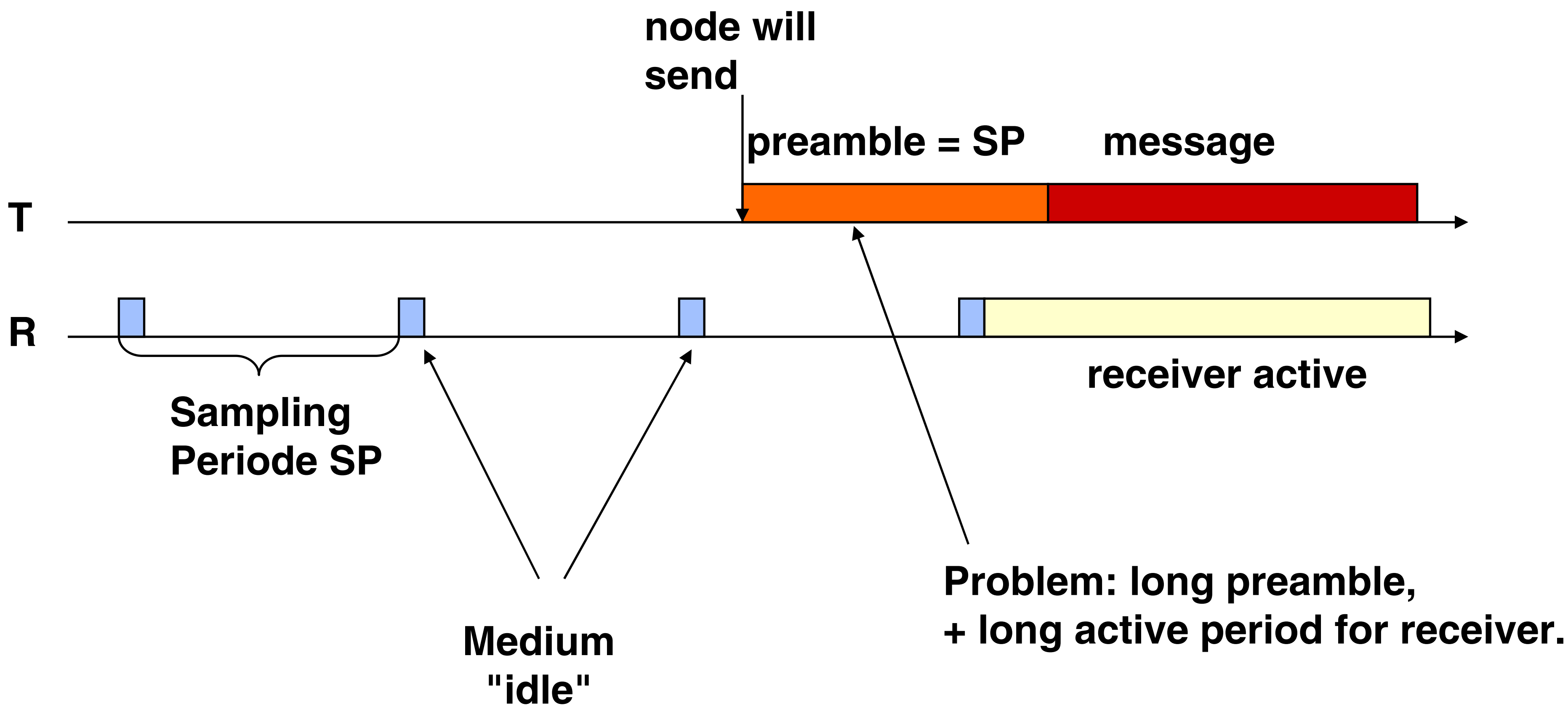
A. El-Hoiyi: Aloha with preamble sampling for sporadic traffic in ad-hoc wireless sensor networks, IEEE Int. Conf. on Comm. (ICC) New York, Apr. 2002

Low Power protocol: WiseMAC

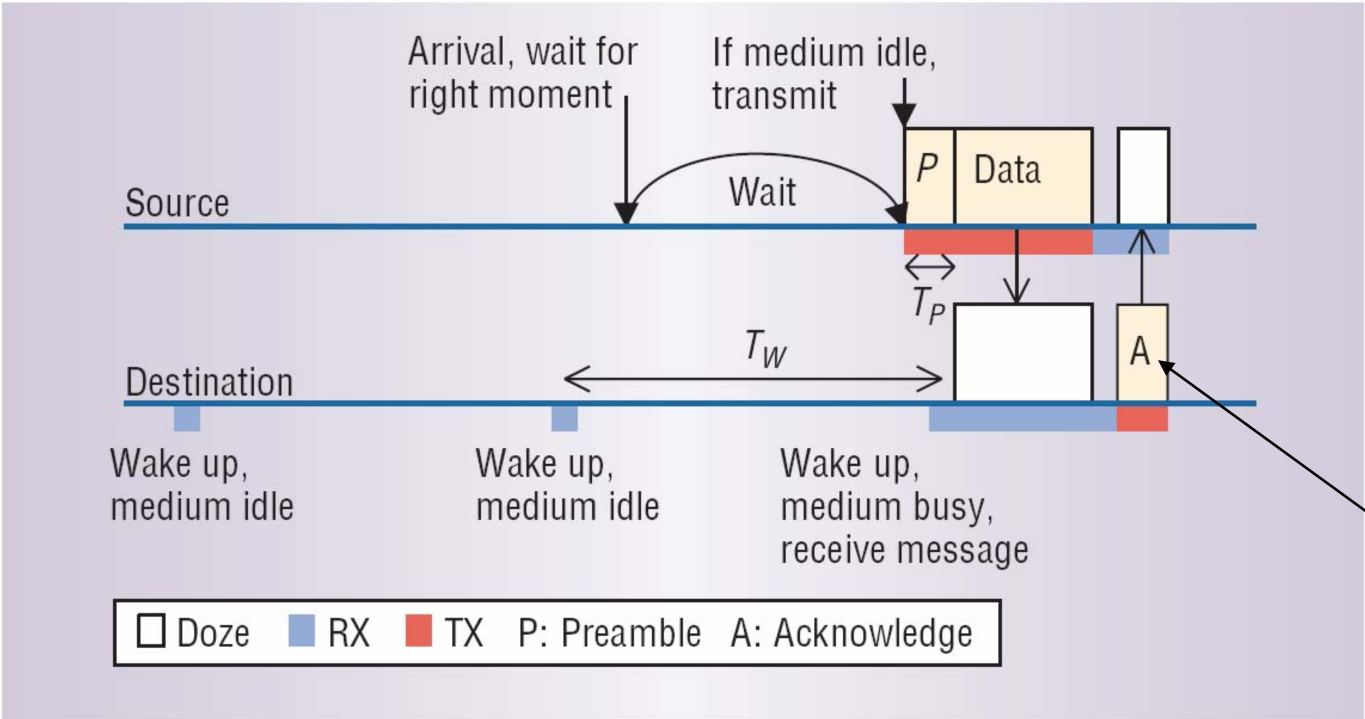
Christian C. Enz, Amre El-Hoiydi, Jean-Dominique Decotignie, Vincent Peiris (Swiss Center for Electronics and Microtechnology):
WiseNET: An Ultralow-Power WirelessSensor Network Solution, IEEE Computer, August 2004

WiseMac exploits an optimized form of "Preamble Sampling"

Standard Preamble Sampling



Low Power protocol: WiseMAC

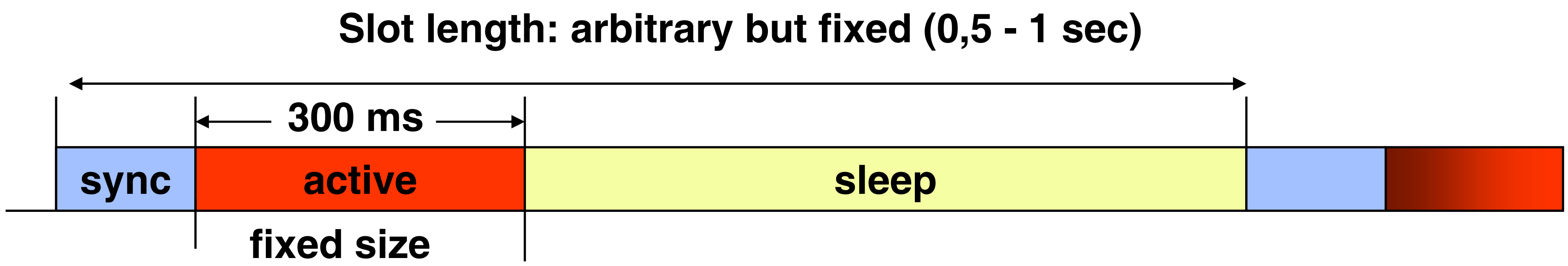


sampling period is piggy-backed in the ack.

In WiseMAC the sender adapts to the receiver's sampling period.

Christian C. Enz, Amre El-Hoiydi, Jean-Dominique Decotignie, Vincent Peiris (Swiss Center for Electronics and Microtechnology): WiseNET: An Ultralow-Power WirelessSensor Network Solution, IEEE Computer, August 2004

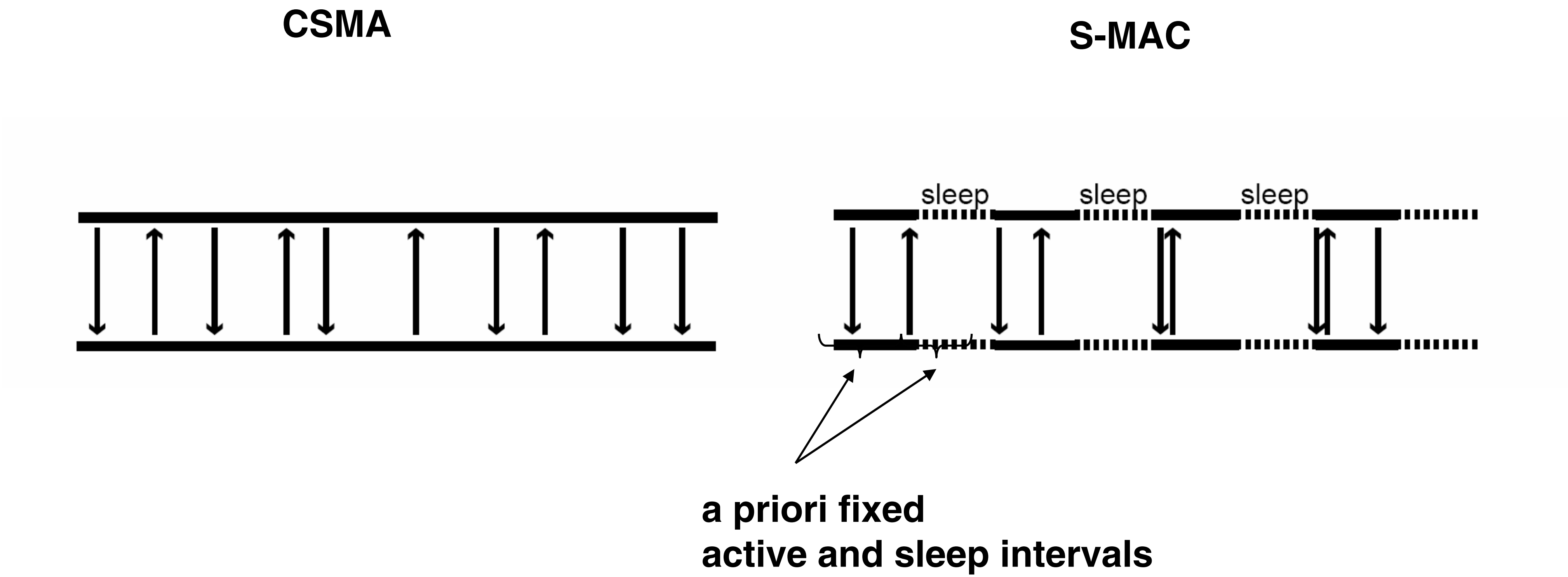
Slotted protocols



Example: S-MAC (Sensor -MAC) (Ye, Heideman, Estrin)

Nodes are organized in (virtual) clusters, which adopt a common slot format.

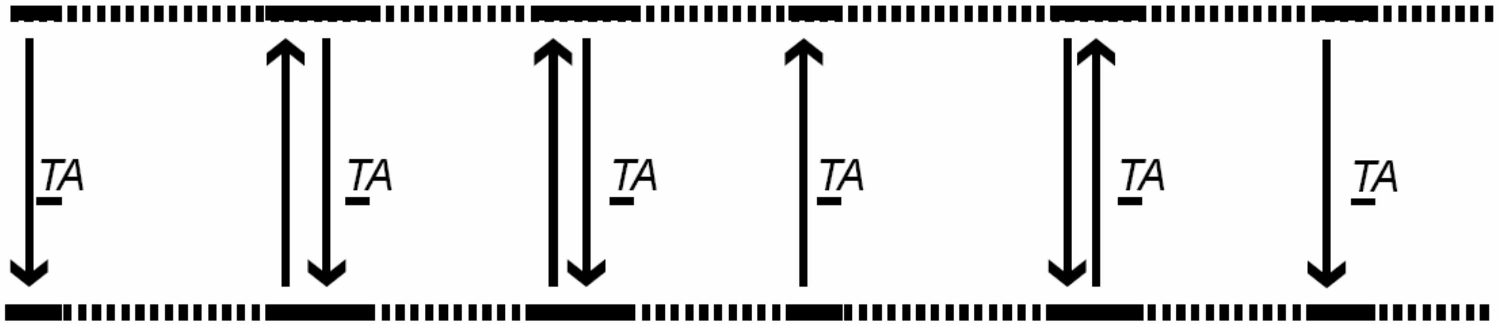
Variation T-MAC (Time-out MAC): Adaptively determining the relation between active and sleep perods. If the medium is idle the node can switch to sleep after a short interval.



During the activity periods the node must transmit local data + the messages which are relayed in the multi-hop network.

Problem with S-MAC: fixed periods

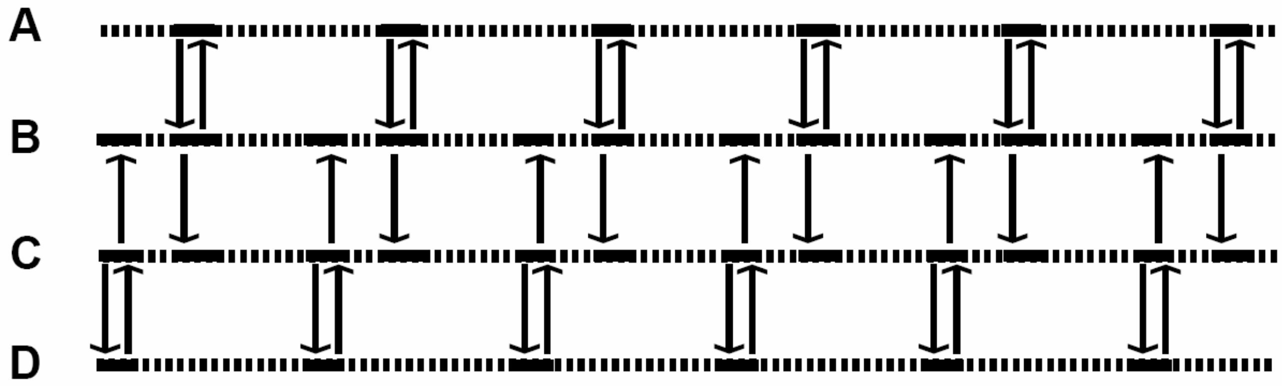
T-MAC: Time-Out-MAC



Determine the activity and sleep periods adaptivly.

An activation event is given by:
- Alarm of a periodic timer;
- Reception of a message;
- Detection of some communication (also collisions are such events);
- Termination of the own transmision or of an ack.
- The knowledge that a communication by some neighbors has been terminated. (detected by overhearing)

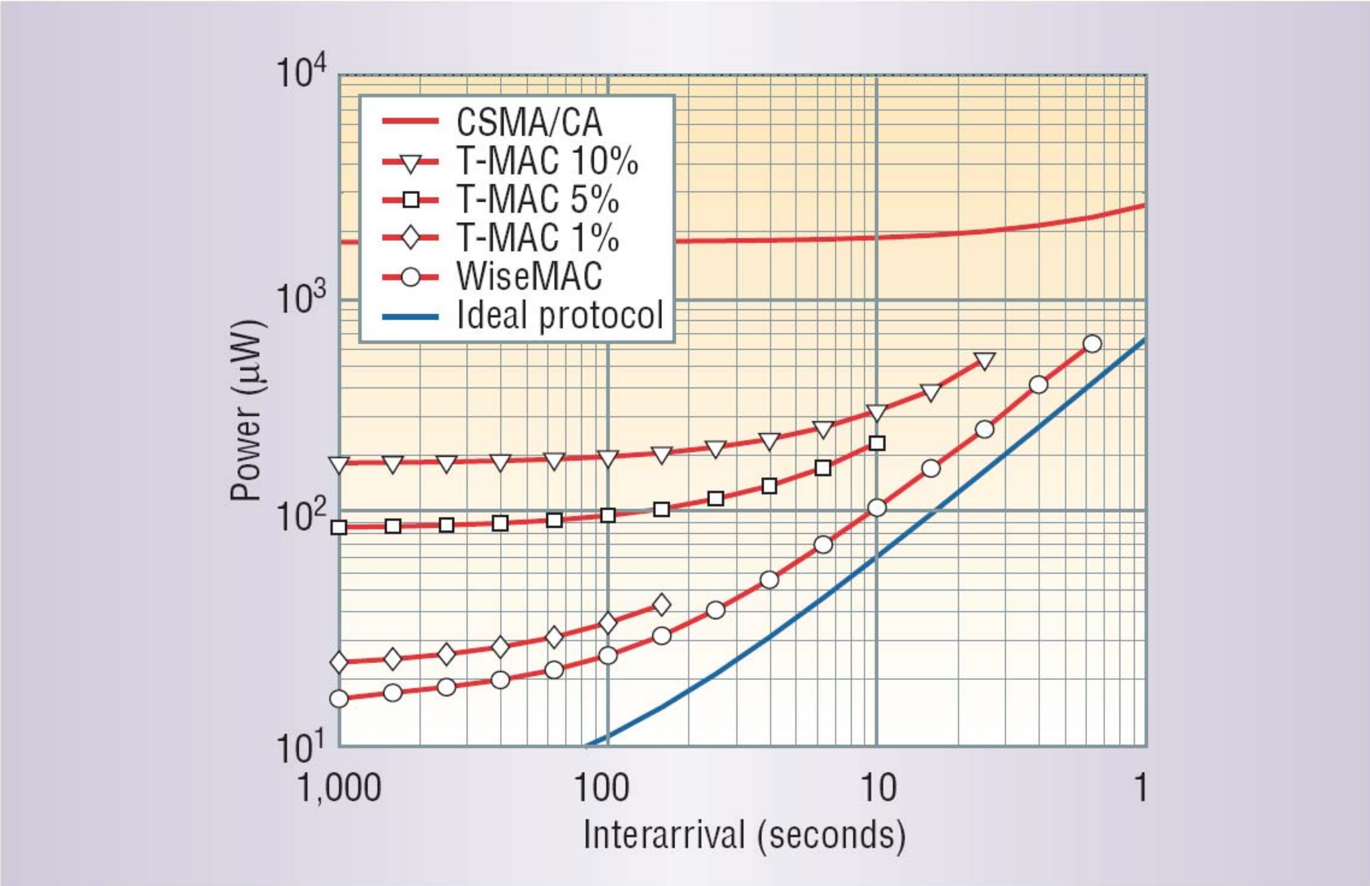
All communication is performed in "bursts" at the start of the aktive period.



Communication between
"virtual clusters" in T-MAC

Messages to relay will be buffered. The size of the buffer determines the upper bounds of activity and sleep periods.

Comparing Low Power Protols; every node has 8 neighbors.



T-MAC:
% of packet loss because of collisions.

WiseMAC:

"With an interarrival time of 100 seconds, the power consumption amounts to as little as 25 microwatts—which translates into more than a five-year lifetime for a single AA alkaline battery."

Christian C. Enz, Amre El-Hoiydi, Jean-Dominique Decotignie, Vincent Peiris (Swiss Center for Electronics and Microtechnology):
WiseNET: An Ultralow-Power WirelessSensor Network Solution, IEEE Computer, August 2004

Embedded Networks

- o Introduction
- o Models of communication
- o Dependability and fault-tolerance
  - * Attributes and measures of Dependability
  - * Basic techniques of Fault-Tolerance
- o Time, Order and Clock synchronization
- o The physical network layer
- o Protocols for timely and reliable communication
  - * Controller Area Network (CAN-Bus)
  - * Time Triggered Protokoll (TTP/C)
  - * Byteflight, Flexray
  - * LIN, TTP/A
  - * Token protocols
- o Sensornets
  - * Protocols for wireless communication
  - * Energy-efficient MAC-protocols