Topic

INDOOR RADIO LOCAL AREA NETWORKS

Focus

PERFORMANCE ANALYSIS OF A TOKEN BASED MAC-PROTOCOL WITH ASYMMETRIC POLLING STRATEGY ('TOPO') UNDER CHANNEL OUTAGE CONDITIONS

by

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Outline

1. Wireless Connectivity
2. Indoor Radio Environment
3. MAC Protocol Objectives
4. TOPO Protocol
5. Simulation Model
6. Performance Evaluation
7. Summary and Outview

1. WIRELESS CONNECTIVITY

Advantages

Opportunity to establish, reconfigure or extend LANs very flexibly

Need for wiring eliminated -> cost and time benefits

Mobility for costumer

Disadvantages

Common medium for all users -> regulations for bandwidth limitation

High bit error rate (10^{-2})

Limited data rate (<10 Mbit/s)

Portable power supply needed

Trends

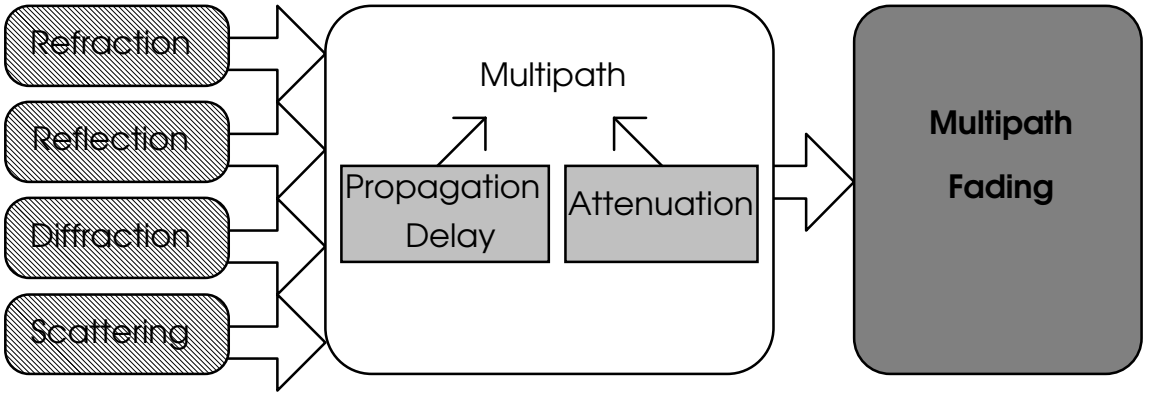
Wireless LANs as extension to existing high speed networks

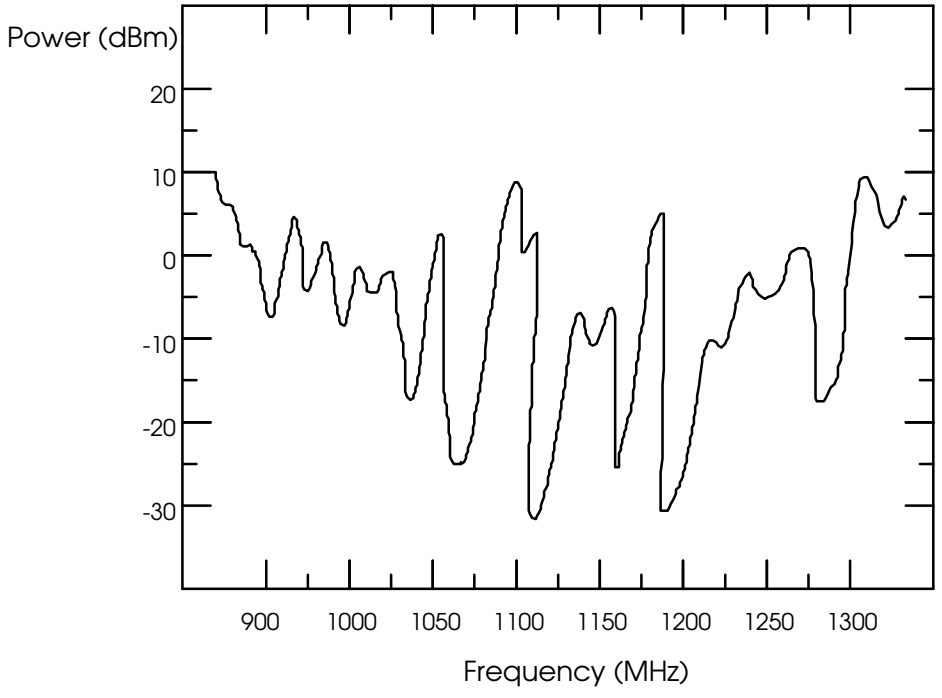
Portable computers with low price and low power consumption

Multimedia applications

2. INDOOR RADIO ENVIRONMENT

Multipath Fading





-> Error bursts for certain bit pattern (recurrent in the data stream)
-> Temporary high BER

Flat Fading

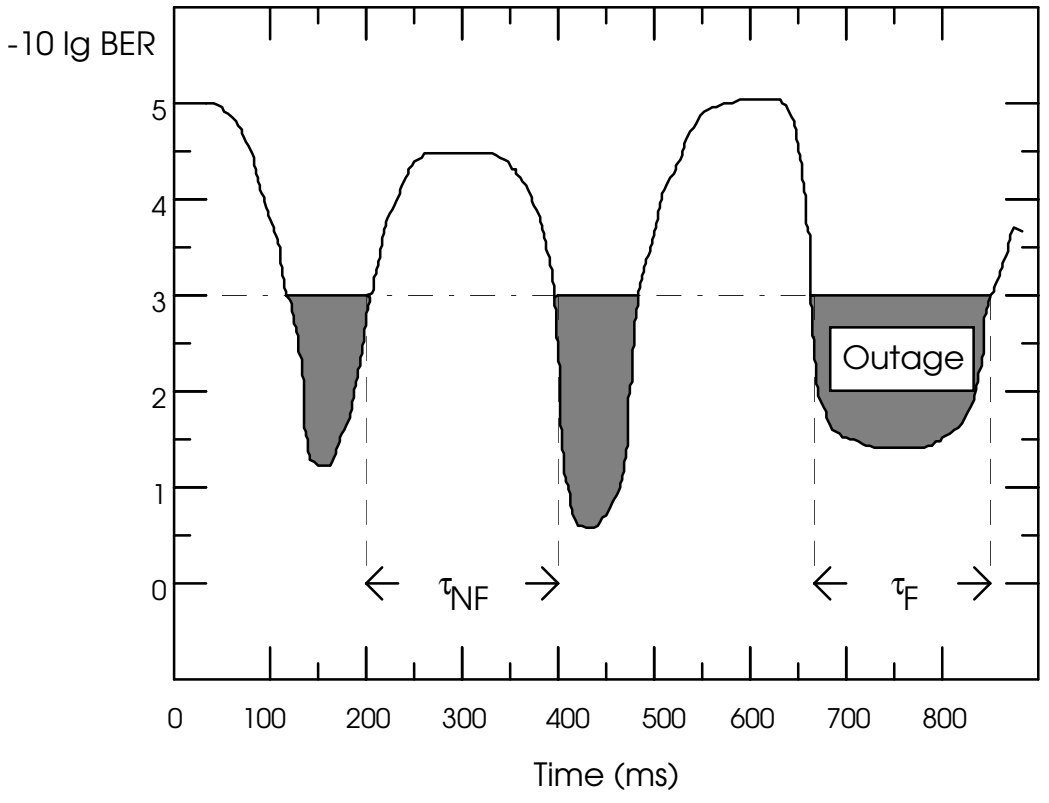
-> SNR drops over entire bandwidth and causes random bit errors
-> Degradation of BER

Channel Outage

Periods of link unavailability

-> Error bursts make data unusable

-> Average BER exceeds the required threshold



Average Non Fade Duration

$\overline{\tau_{NF}}$=20 to 50 ms // Zhang, Acampora

$$f_{\tau_{NF}}(\tau_{NF}) = \frac{1}{\overline{\tau_{NF}}} \exp\left(\frac{-\tau_{NF}}{\overline{\tau_{NF}}}\right)$$ // Linnarz

Channel Outage Probability

$$COP = \frac{\overline{\tau_F}}{\overline{\tau_F} + \overline{\tau_{NF}}}$$

COP=10^{-1} to 10^{-3} // Greenstein

3. MAC PROTOCOL OBJECTIVES

Support of different traffic types

Synchronous traffic: bounded response delays

Asynchronous traffic: access to a large bandwidth for a short period of time

Performance under heavy loading

Maximization of bandwidth utilization

No infinite response delays

Performance under channel outage

Robust in handling loss of protocol primitives

Minimum bandwidth wastage for synchronization

General considerations

Network topology

Complexity of protocol stack

User requirements

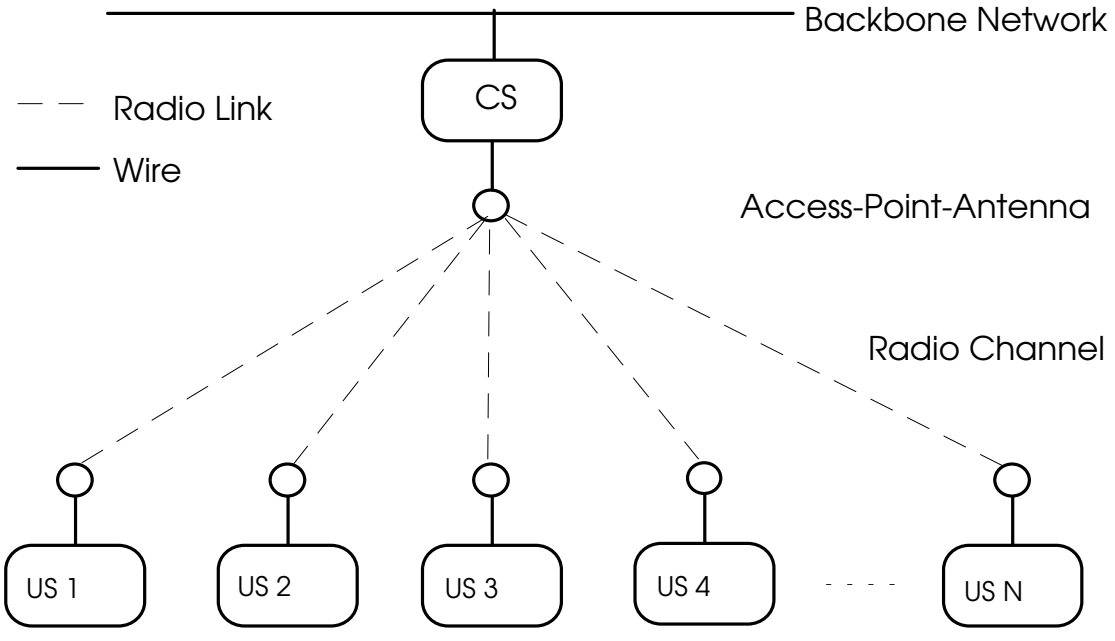
Costs and feasibility

4. TOPO PROTOCOL

Topology

-> Centralized system

-> Bandwidth allocated to user stations (US) by central station (CS)



Primitives

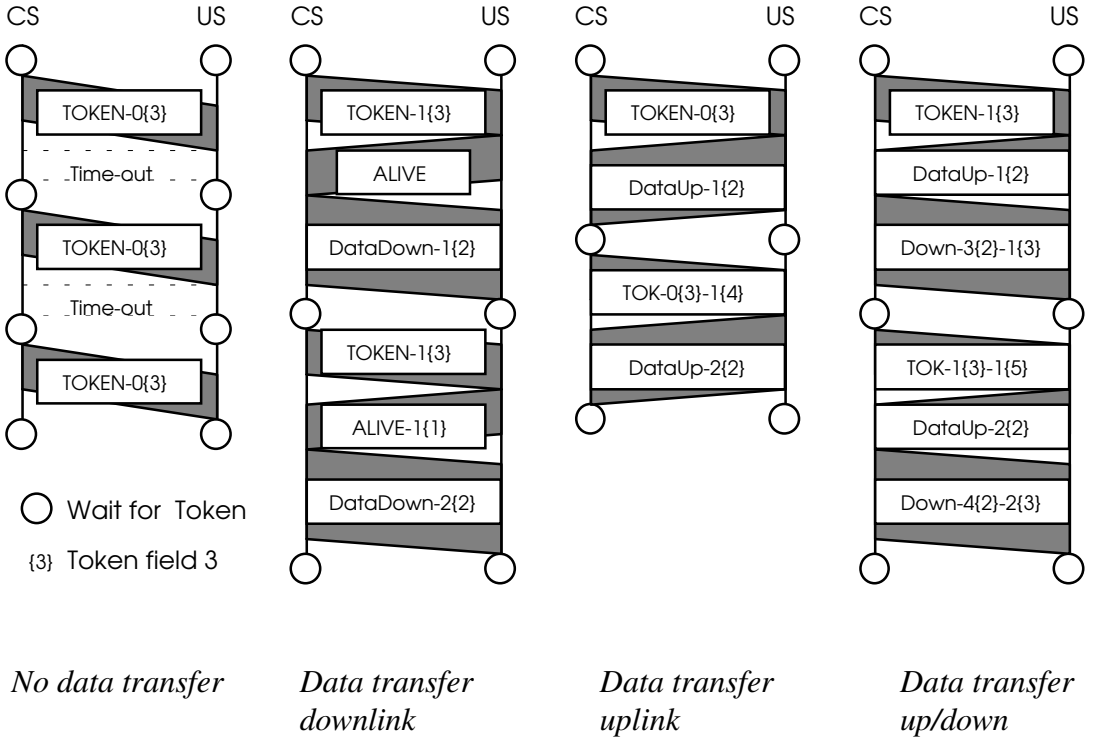
User	Primitive	I-field 1	I-field 2	I-field 3	I-field 4	I-field 5	I-field 6
CS	***Token***	Multicast Flag	US address	Buffer Flag	Traffic Flag	LID_US	<control data>
CS	***Open Token***	open address	backoff n				
US	***RTJ***	ID					
US	***ALIVE***	LID_CS					
US	***DataUp***	data	ID	LID_CS			
CS	***DataDown***	data	ID	LID_US			

Polling

-> According to priorities (traffic type, buffer status at CS)

Unicast Data Transfer

-> Token_Buffer Flag='1' -> DataDown ready for transmission
-> Success of transmission -> Comparison ID with LID
-> Token_control data -> Packet size limit for DataUp



No data transfer *Data transfer downlink* *Data transfer uplink* *Data transfer up/down*

Fig.: Uncorrupted data transfer in the unicast mode

Solicited data transfer

-> Retransmission in the case of data corruption

Unsolicited data transfer

-> Token_Traffic Flag='1'
-> Time-out replaces ALIVE primitive
-> No retransmission of corrupted data
-> ID/LID used to perform statistics

Multicast Data Transfer

-> Token_Multicast Flag='1' -> Token_US address=group address

-> Success of transmission -> Comparison of ID with LID

-> Retransmission for solicited data in the the unicast mode.

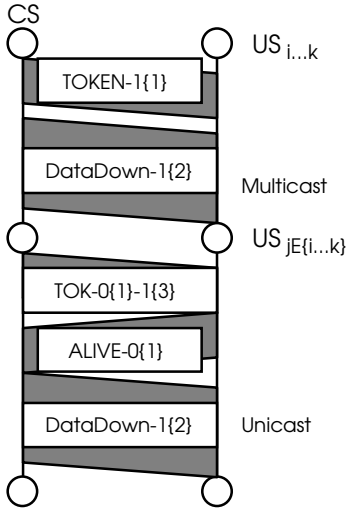


Fig.: Multicast data transfer with retransmission in the unicast mode

Joining the network

-> Open Token_open address is offered as US address

-> Channel access random with RTJ primitives

-> Success of access -> Token_US address=open address
-> Comparison of ID with LID

-> Collision resolve algorithm:

$$m=random(0,2^n)$$

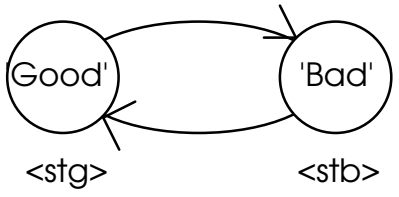
5. Simulation Model

Assumptions

-> User station can request a data packet served by the central station
-> Asynchronous data -> retransmission in the case of corruption
-> Service immidiately after request reception (ideal conditions)
-> Higher priority for retransmission
-> Single request buffers at N=30 user stations
-> Unlimited buffer at the central station
-> Request interarrival times are neg. exp. distributed, mean value λ

Channel Outage

-> Two state continuous time Markov chain
-> Sojourn times neg. exp. distributed, mean values: stg and stb



Parameters

r	Primitive transmission time (except data packets)
p_{tt}	Data packet transmission time
$\lambda N p_{tt}$	Load
E[T]	Mean response time
ρ	Bandwidth utilization

Hardware and Software Specification

-> SUN SPARC
-> C++
-> Simulation time=$100000 p_{tt}$

6. Performance Evaluation

Ideal conditions

N=30 r=100 bit/RATE p_{tt}=10 kbit/RATE RATE=10 Mbit/s

Fig: Impact of varying packet transmission time on the utilization

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Fig.: Impact of varying packet transmission time on the mean response time

Optimum packet size

$\lambda N p_{tt} \in [0.01,15]$ N=30 r=100 bit/Rate RATE=10 Mbit/s COP=10^{-2}

Fig.: Optimum packet transmission time for stg=0.01 s

Impact of varying COP

$\lambda N p_{tt} \in [0.01,2]$ N=30 r=100 bit/Rate RATE=10 Mbit/s stg=0.05 s p_{tt}=0.05stg

Fig.: Impact of varying COP on the utilization

Impact of varying COP

$\lambda N p_{tt} \in [0.01,2]$ N=30 r=100 bit/Rate RATE=10 Mbit/s stg=0.05 s p_{tt}=0.05stg

Fig.: Impact varying COP on the mean response time

Error correction mechanism

$\lambda N p_{tt}=1$ N=30 r=100 bit/Rate RATE=10 Mbit/s stg=0.05 s $p_{tt}=0.05$stg

Fig.: Coding gain for FEC coding in conjunction with ARQ

Error correction mechanism

$\lambda N p_{tt}=1$ N=30 r=100 bit/Rate RATE=10 Mbit/s stg=0.05 s $p_{tt}=0.05$stg

Fig.: Coding gain for adaptive equalization in conjunction with ARQ

7. Summary and Outview

Ideal Conditions

$$E[T]_{max}=N(p_{tt}+2r) \qquad \rho_{max}=\frac{p_{tt}}{p_{tt}+2r}$$

-> Throughput maximizes to nearly 100% under heavy load and negligible small r

-> Mean response time bounded

Channel Outage Conditions

stg [s]	**p_{ttopt}/stg**	**p_{ttopt}*RATE [Kbit]**	**p_{ttopt}/r**
0.001	0.1	1	10
0.005	0.1	5.1	52
0.01	0.05	5.1	52
0.05	0.05	25.6	262
0.1	0.01	10.2	105

-> Optimum packet transmission time is about 5% stg (COP=10^{-2})

COP	**ρ_{max}**	**Wastage [%]**	**stb/p_{tt}**
0	99.0	0	0
10^{-6}	94.1	4.9	0.00002
10^{-4}	94.1	4.9	0.002
10^{-3}	94.1	4.8	0.02
10^{-2}	93.9	4.1	0.2
10^{-1}	86.7	2.3	2

-> Bandwidth wastage to recover from outage is less than 5% ($\lambda N p_{tt}=2$)

Error Correction mechanism

-> Combination of retransmission and error correction techniques only justified if the COP is high and the coding overhead can be compensated for

Conclusion

-> Protocol suitable for indoor radio environment

Future work

Simulations that incorporate:

-> Synchronous data
-> Alternative data arrival models, e.g., packet train arrival
-> Asymmetric load conditions

Acknowledgements

Tenet group at the ICSI and UC Berkeley and Dave Johnson