Performance Improvement of TCP in Wireless Cellular Network Based on Acknowledgement Control

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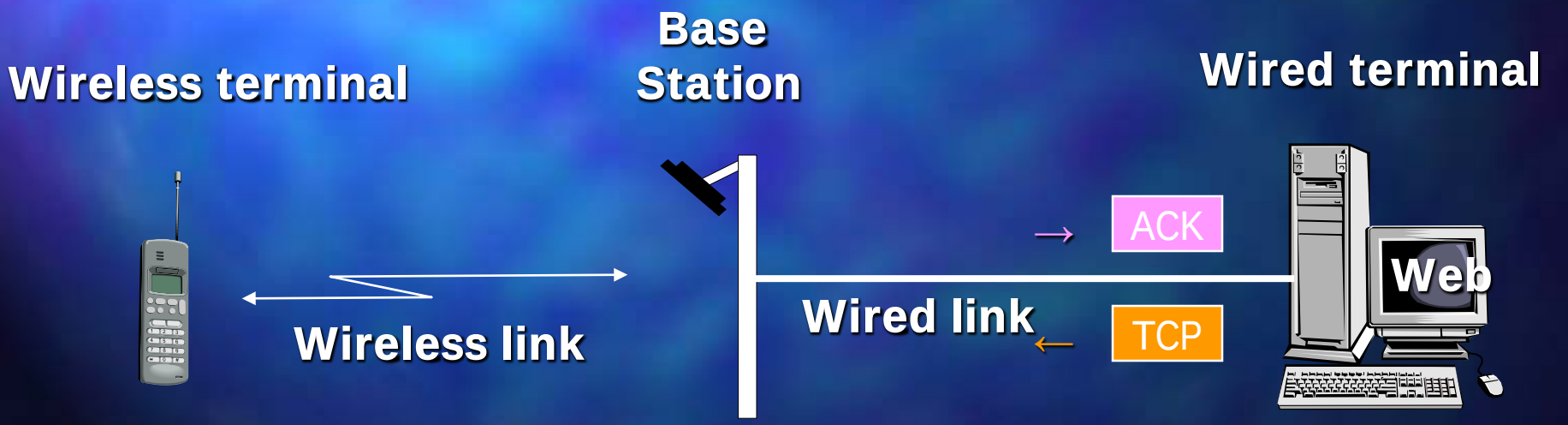
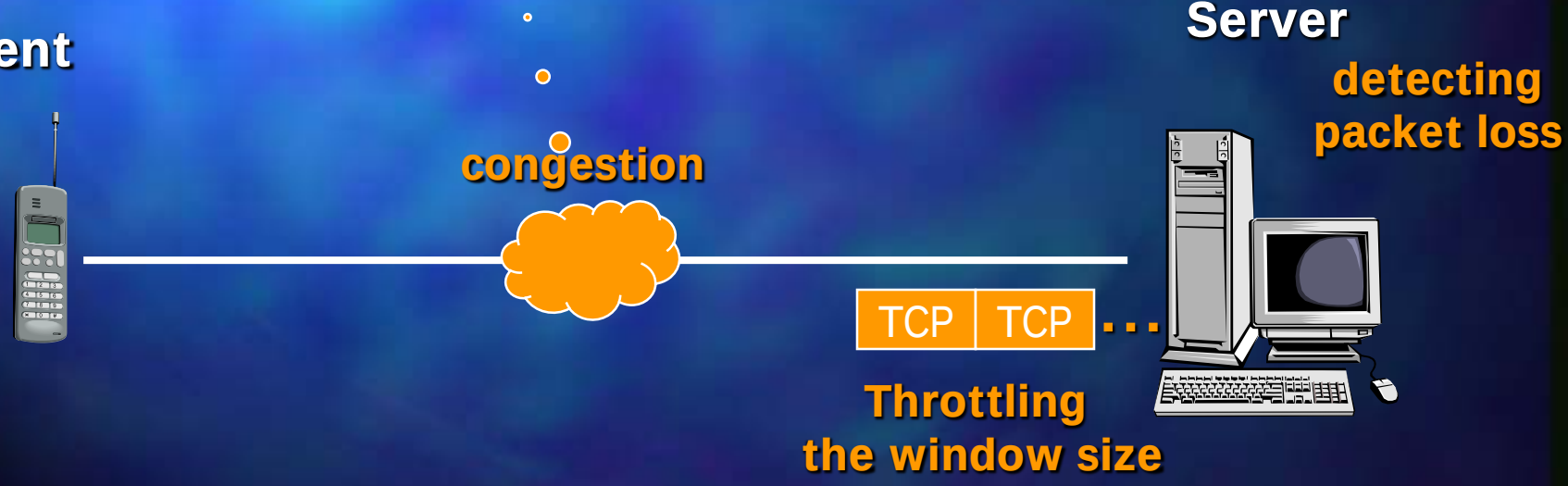
TCP over wireless cellular network

[In the case of Web documents downloaded]
TCP segment is transmitted from the wired terminals towards the wireless terminal, between wireless link and wired link.



TCP Congestion control

TCP uses a window-based congestion control.
When packet loss is detected,
TCP recognizes the congestion occurrence of the network and throttles the window size.



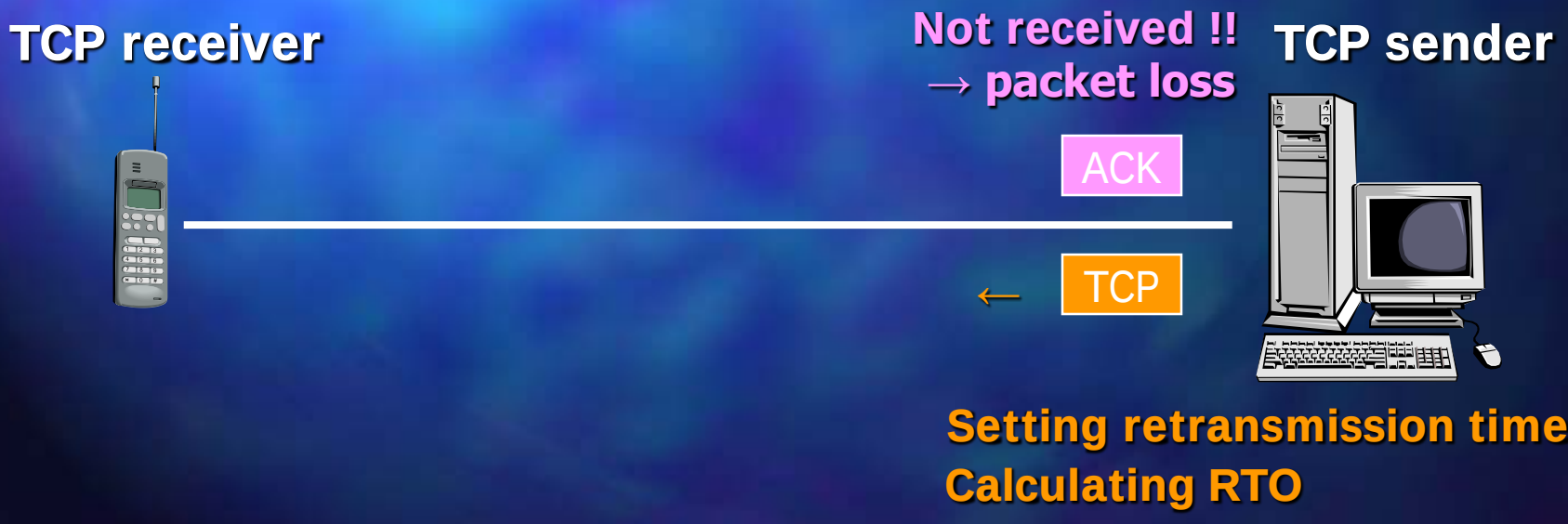
How to detect packet loss

There are two primarily mechanism

- Retransmission timeout
- Duplicate ACK

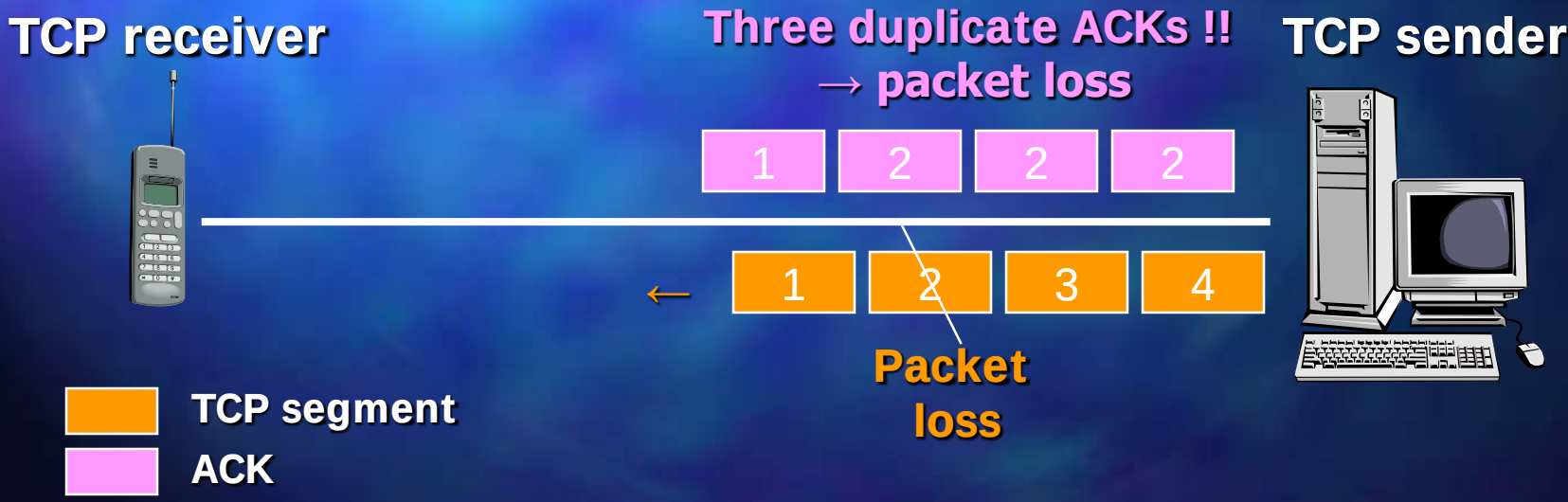
Retransmission timeout

- TCP sender sets retransmission timer.
- TCP sender calculates RTO=f(RTT) .
- If the ACK for the timed packet is not received, before the timer overflow, the packets is assumed to be lost.



Duplicate ACK

- TCP sender sends TCP segment added on sequence no.
- TCP receiver sends ACK added on sequence no, which should be received.
- If triple duplicate ACKs are received continuity, the packets is assumed to be lost.



TCP over wireless link

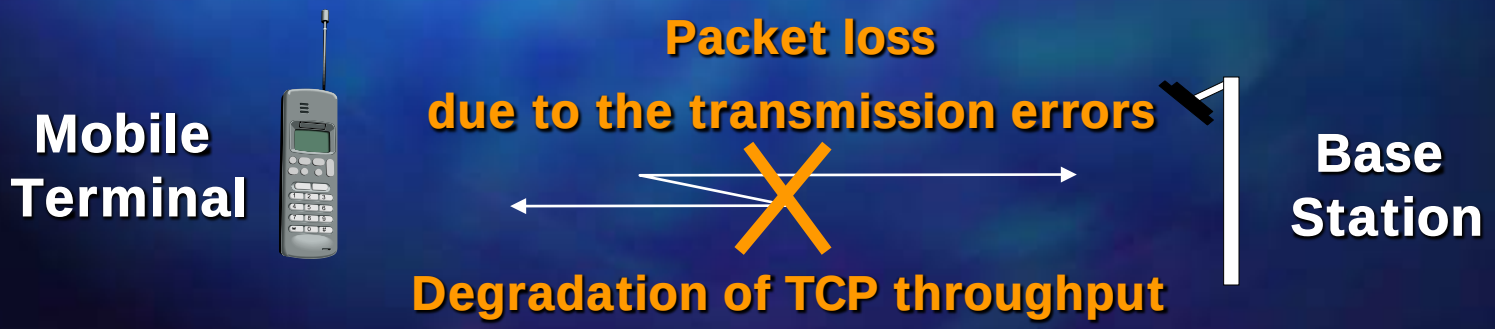
On a wireless link, packet loss occurs due to transmission errors.

↓

TCP can not distinguish packet loss between due to congestion and due to transmission errors.

↓

Packet losses due to the transmission errors cause unexpected degradation of TCP throughput.



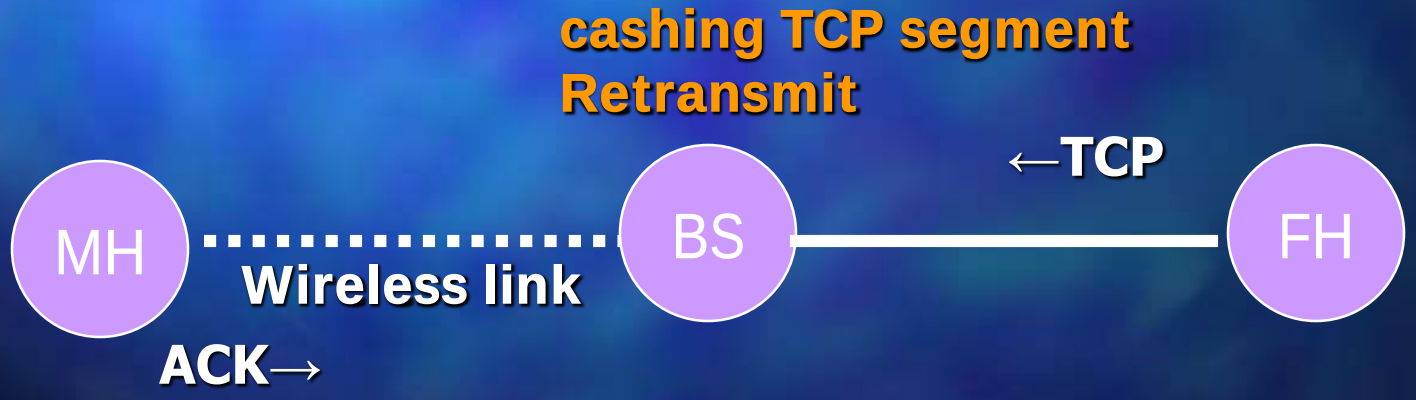
Past researches

- Snoop Protocol -

Snoop Protocol [Balakrishnan95acm]

(1) The TCP segments are cashed at the base station.

(2) The TCP segments are retransmitted at the base station, if packet loss is detected on wireless link.



Past researches

- ELN -

Explicit Notification[Biaz99thesis]

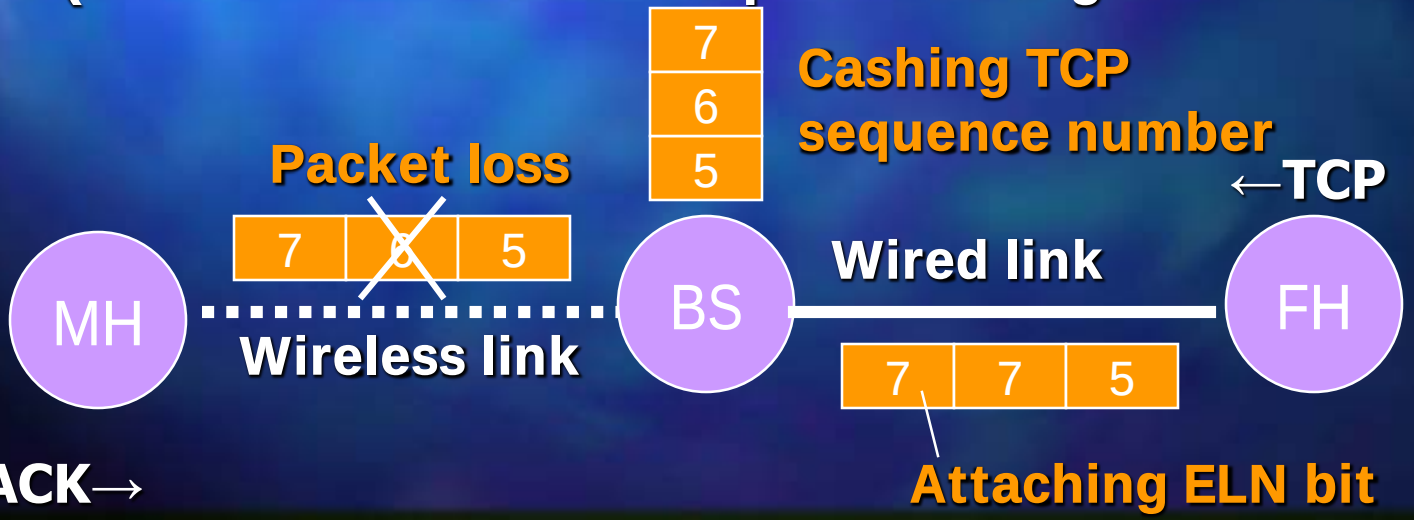
(1) The TCP segment sequence numbers are cashed at BS.

(2) The packet is lost on the wireless link.

(3) The ACK packet is attached “ELN bit active” at BS, if the packets cashed sequence number is lost.

(4) FH takes appropriate action receiving ELN bit.

(ex. TCP sender does not perform congestion control.)



Past researches

- Disadvantage -

Snoop Protocol

- Buffering TCP segment at BS
- Retransmission TCP segment at BS

Explicit Notification

- Cashing TCP sequence number at BS
- Attaching ELN bit at BS
- Receiving ELN bit and appropriate action at FH

Above solutions have not been realized (because these require major changes to network infrastructures)

Objectives

New method for improving the performance of TCP by a minor change

We propose a method for improving the performance of TCP in treating the ACK packets

Proposed Method

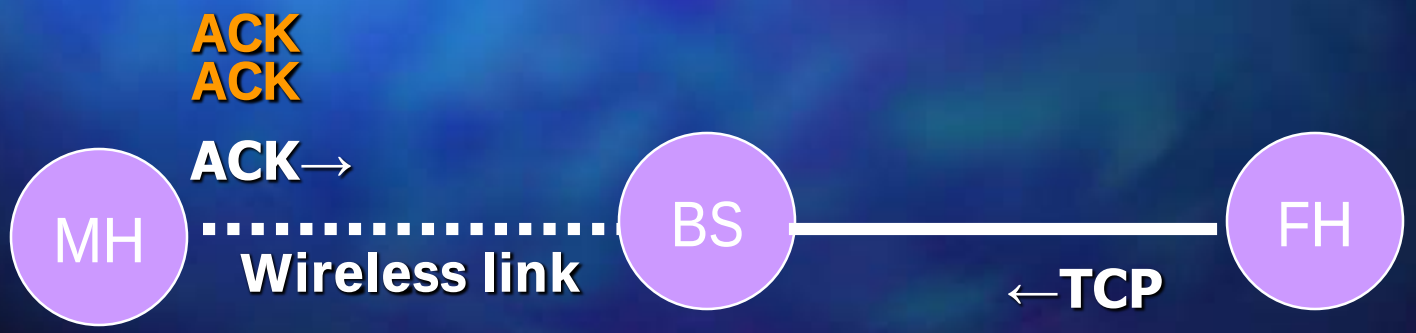
TCP receiver does not send one ACK, but multiple ACKs

↓

TCP would becomes robust against transmission errors

Proposed Method

(1) FH receives one ACK
→it continues the normal operation
(2) FH receives more than two ACKs
→it recognizes as duplicate ACKs
(3) Only if all of multiple ACKs are lost
→ the timeout occurs at the FH.



Proposed Method

- Appropriate number of ACKs -

- It is effective in transmitting two or more ACKs in the range of the high transmission error rate
- On the other hand, if the error rate is low, the TCP performance might deteriorate.

Appropriate number of ACKs ?

Proposed Method

- Deriving appropriate number of ACKs -

We derived appropriate number of ACK using following expression

Packet loss rate

Duplicate ACK Transmission error

$$p(n) = p_{buff}(n) + p_{err}(n) - p_{buff}(n)\,p_{err}(n)$$

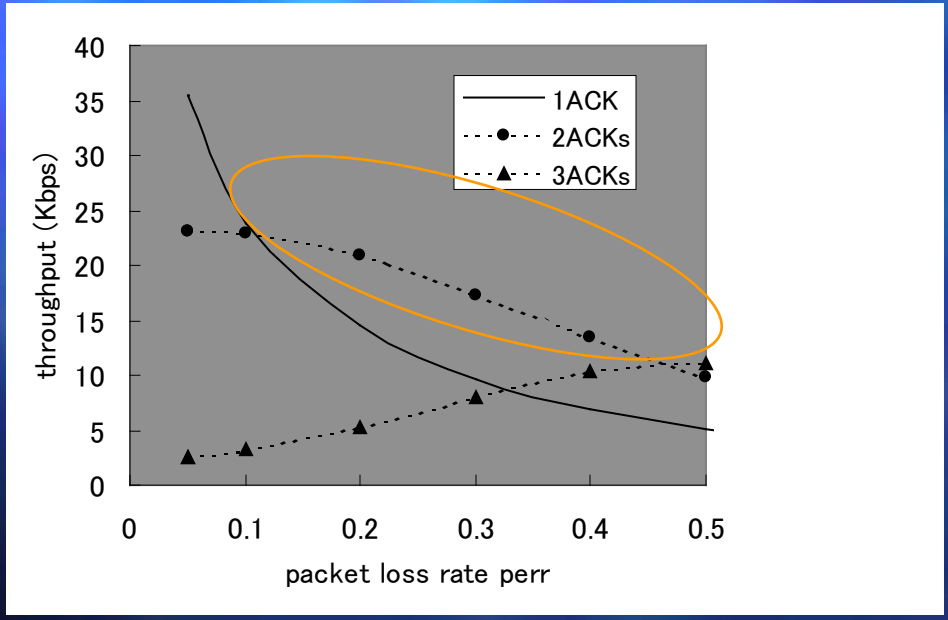
$$S_{TCP} = \frac{1}{RTT\sqrt{\frac{2bp}{3}} + To\min\left(1, 3\sqrt{\frac{3bp}{8}}\right)p\left(1+32p^2\right)}$$

Round trip time Time out time

Proposed Method

- Analysis result -

Transmission of two ACKs can achieve the best performance in the range of $0.1 < p_{err} < 0.47$.



Parameter sets

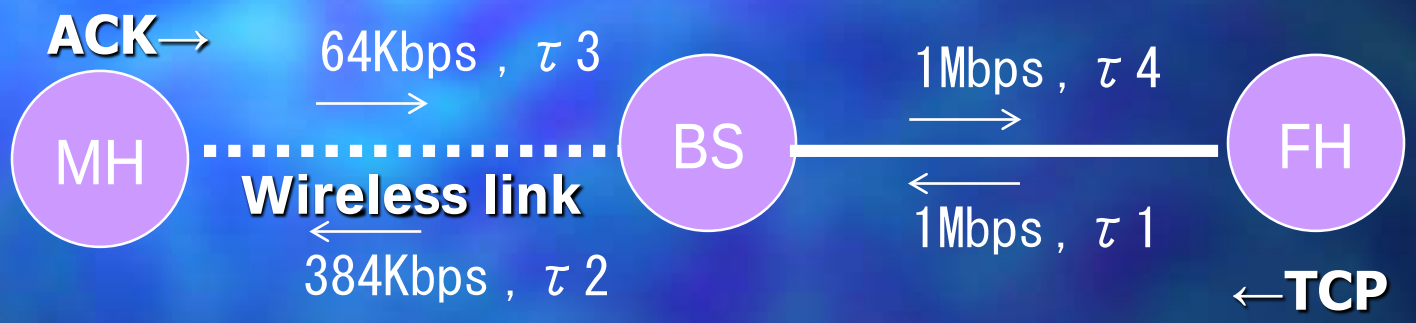
Round Trip Time (RTT): 100ms
Time out time (To): 400ms
Paket loss rate (pbuff): 0.01

Evaluation

- Simulation model -

We evaluate our proposed method by ns-2 simulator

[Network Model]



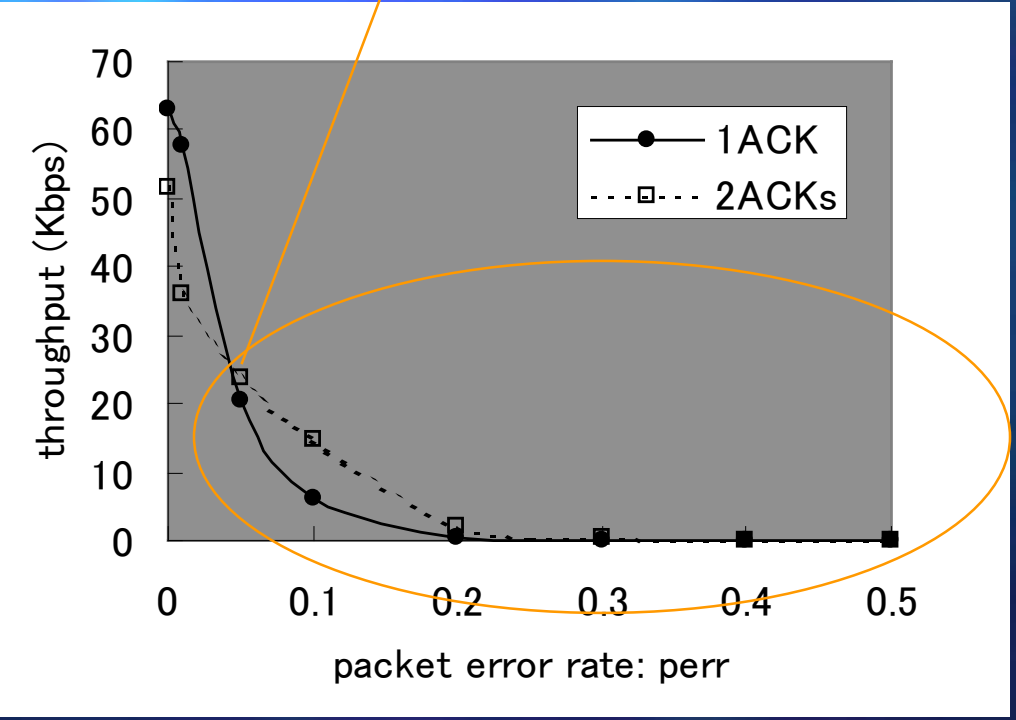
Parameter sets

Number of wireless terminal	1
TCP segment size	100 byte
ACK size	40 byte
Buffer size (Wireless Terminal, BS, Wired Terminal)	50 Kbyte
Propagation delay (τ1,τ2,τ3,τ4)	1 ms

Evaluation

- Simulation result (throughput) -

Transmission of two ACKs can improve the throughput with p_{err} larger than 0.05.

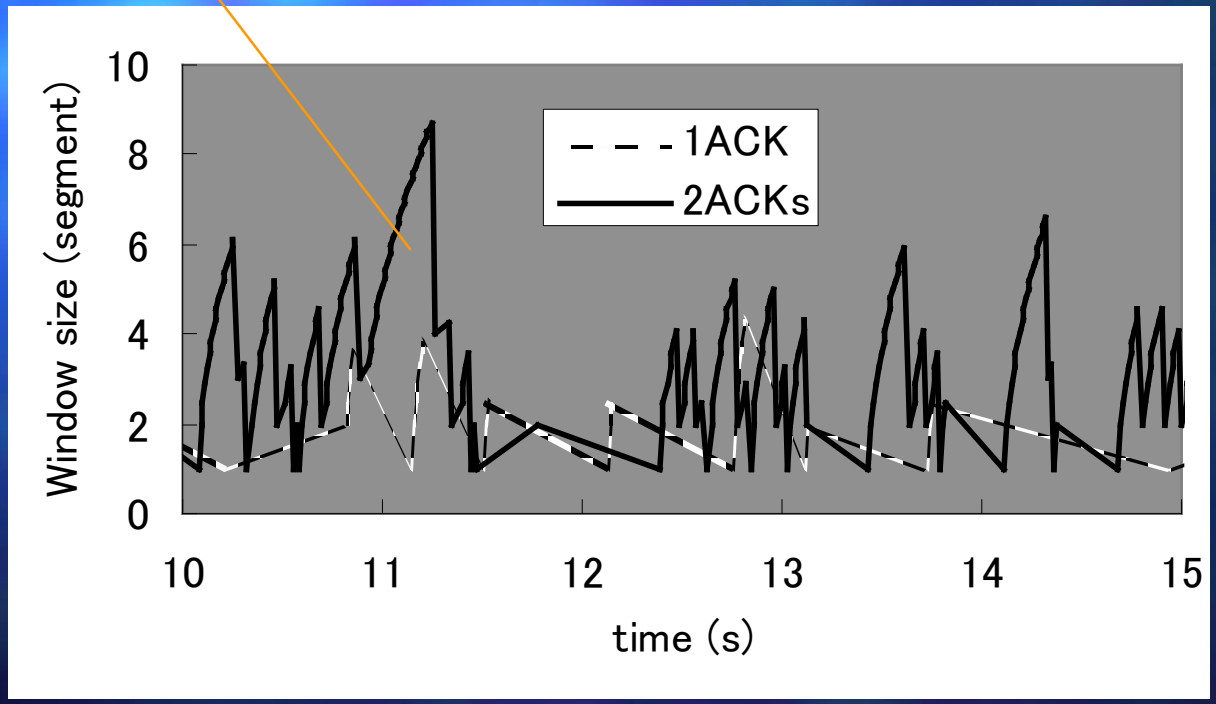


Evaluation

- Simulation result (window size) -

Proposed method is more effective

Larger window size ⇨ Sending more TCP segment



Proposed Method

The wireless terminal sends multiple ACKs, when the packet error probability of the wireless network p_{err} exceeds the threshold value.

We explain the estimation method of packet error rate on the radio link.

Estimation on packet loss rate

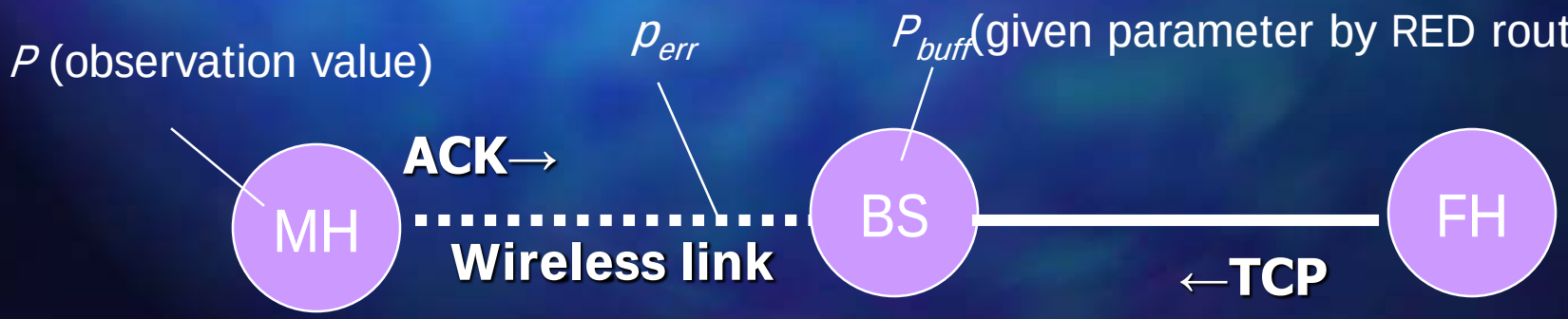
We assumed

p_{err} : Packet loss rate on the radio link

p_{buff} : Packet loss rate on the buffer overflows at the bottleneck buffer

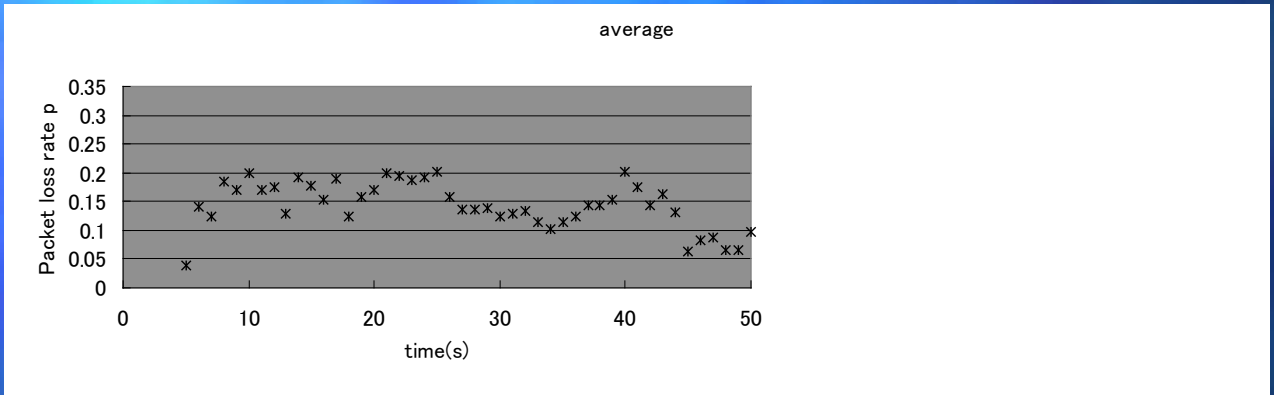
take place independently. p_{err} is represented this expression by observation value p, and given parameter by RED router p_{buff}

$$p_{err} = 1 - \sqrt{\frac{1-p}{1-p_{buff}}}$$



Calculating p by the moving average method

In monitoring p at the wireless terminal, the value of p is changeful



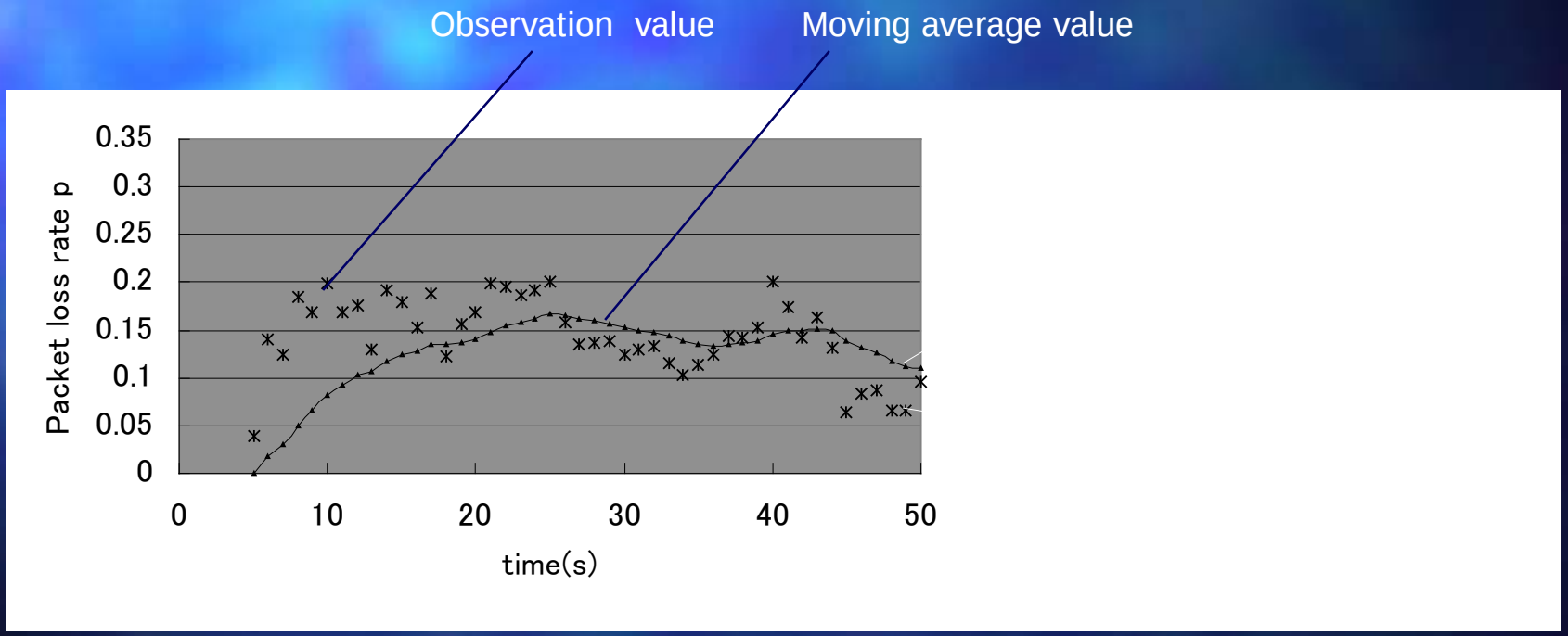
We introduce a method of calculating p by the moving average method, following an estimation method of RTT values in TCP.

$$p[k] = \frac{7}{8} p[k] + \frac{1}{8} p[k-1] \qquad k = 0,1,2\ldots$$

$$p[0] = 0$$

Calculating p by the moving average method

We show the moving average values are good agreements by the simulation, when the number of TCP connections are changed.



Conclusion

- We have presented a method for improving TCP throughput in a wireless cellular network, which needs changes of TCP layer only by the side of a mobile terminal.

- By means of simulation, we have revealed that TCP throughput can be improved in the range with the high error rate of the radio link as we have expected.