Cross-Layer Design to Improve Wireless TCP Performance with Link-Layer Adaptation

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報告：王致凱

Outline

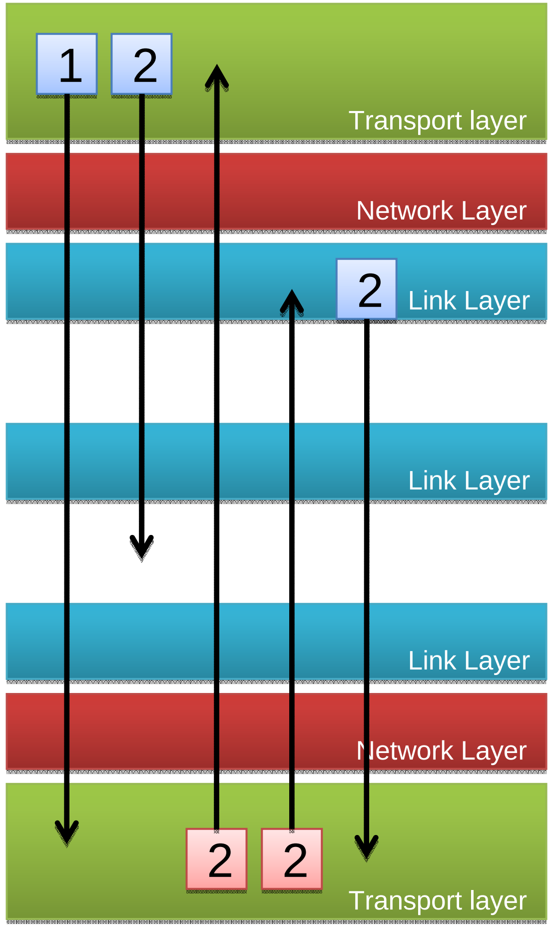
- Introduction
- Related Works
- Design
- Simulation
- Conclusion

Introduction

- TCP is by far the most widely used reliable end-to-end transport protocol supporting congestion control over the Internet.
- Packet loss means network congestion: once timer expire, Congestion Window will be divided by 2.

Related Work

- Proxy TCP
  - Worked by not passing duplicate acknowledgment to the TCP layer.



Related Work

- Reliable Link-Layer
  - ARQ: Causes the RTT to fluctuate
  - Forward Error Correction: May consume extra bandwidth through pro-actively transmitting redundant information

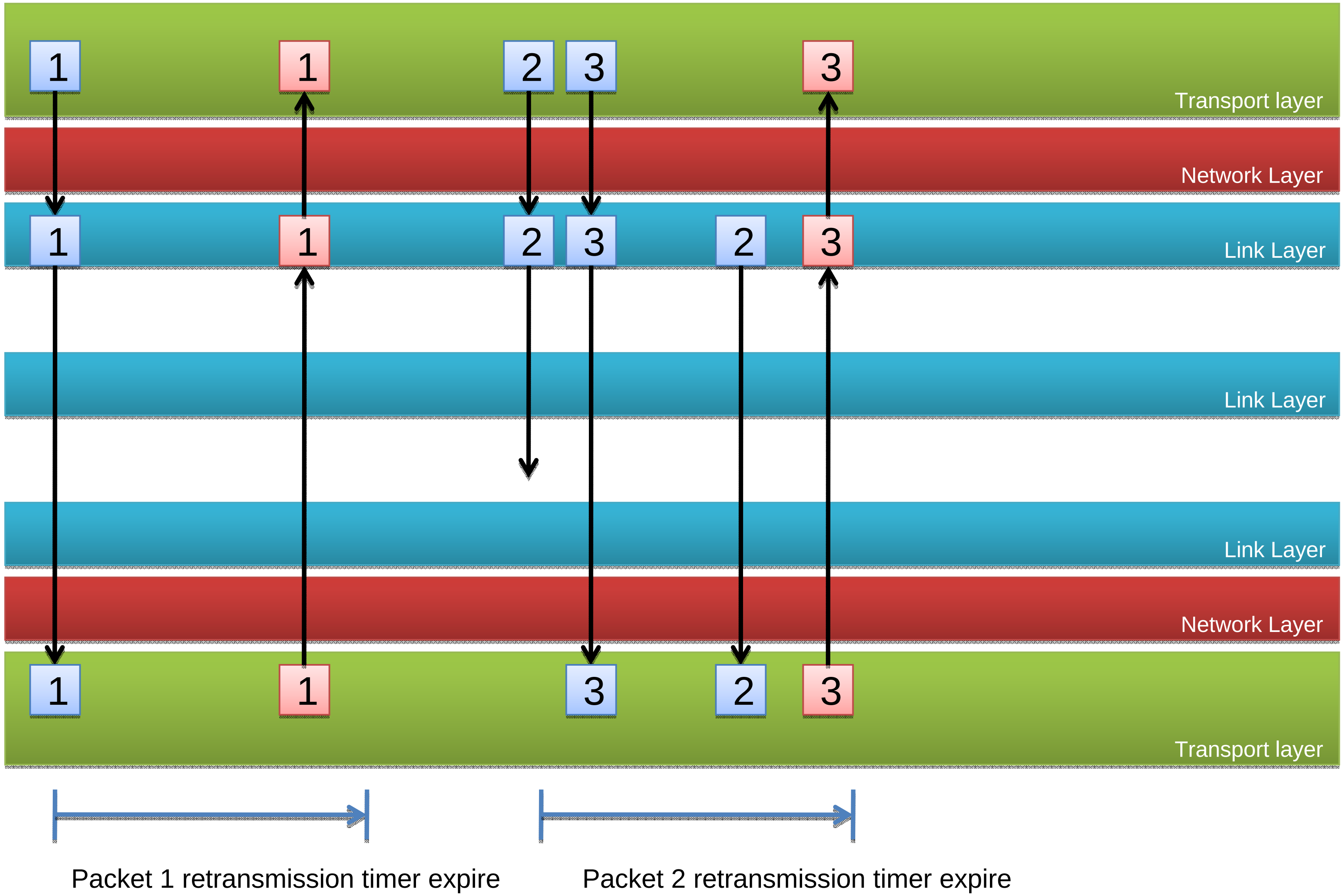
Related Work

- TCP and ARQ
  - ARQ potentially increases the RTT of TCP, may cause TCP retransmission timer expire.

Design

- Perform retransmission at link layer
  - Smaller RTT
  - Hide packet loss from TCP: Congestion window will not be incorrectly altered.

Design

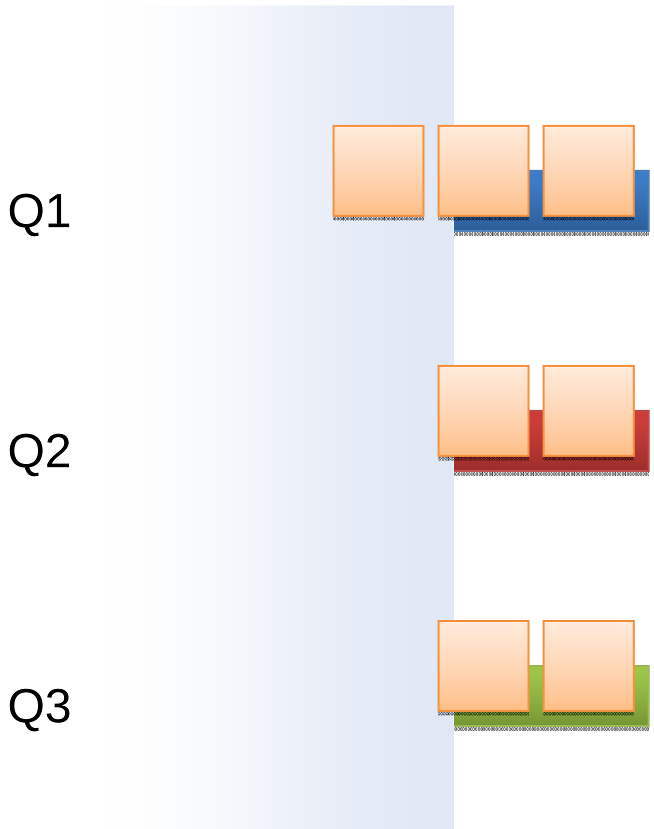

1
1
2
3
3
Transport layer
Network Layer
1
1
2
3
2
3
Link Layer
Link Layer
Link Layer
Network Layer
1
1
3
2
3
Transport layer
Packet 1 retransmission timer expire
Packet 2 retransmission timer expire

Design

- Every non-ACK packet is categorized in a priority queue, according to its weight. The packet weight is assigned based on RTO (Retransmission Time Out)

$$w = 10^4 * n + RTO$$

Design



- Define 3 queues:
  - Q1: never attempted to retransmission
  - Q2: tried once
  - Q3: tried twice
- Compare first packet of each queue: If RTO less than 2*RTT, it will be retransmitted first.

Design

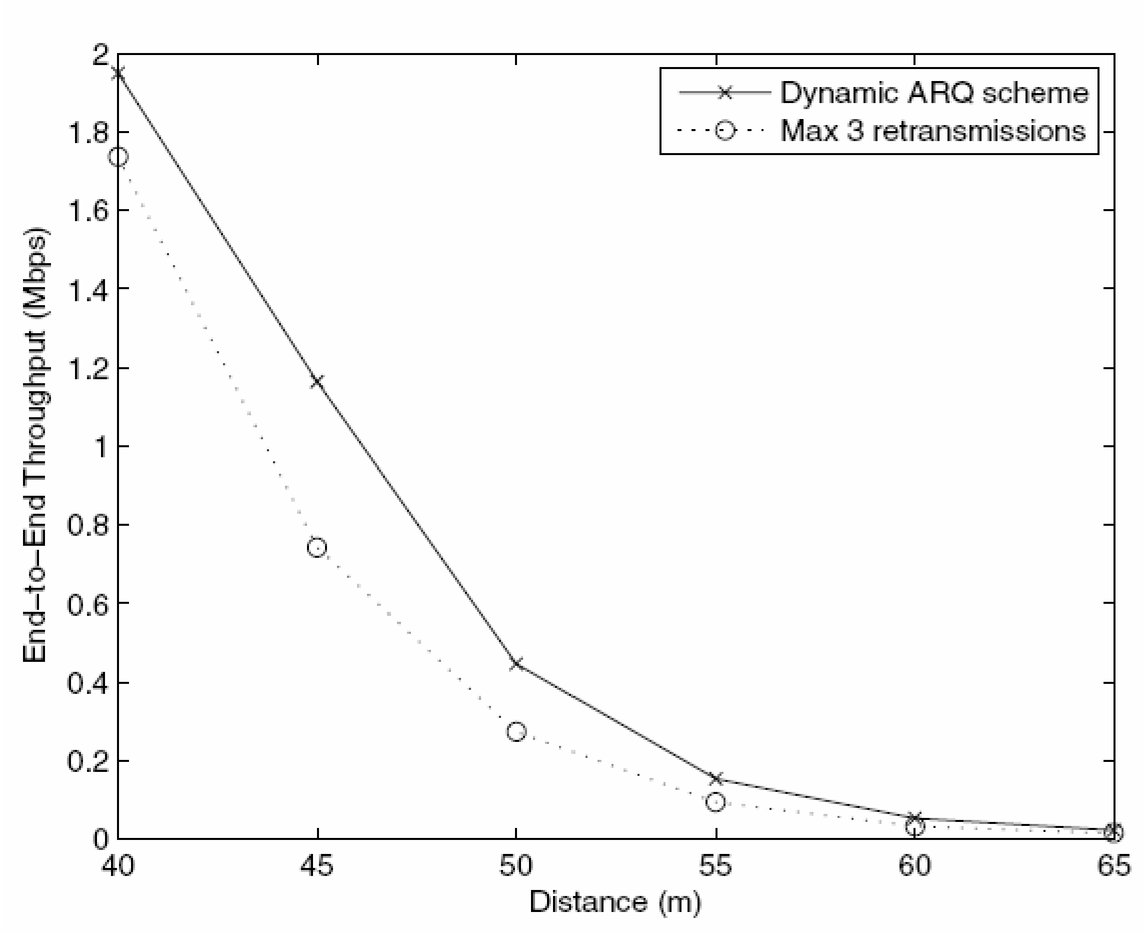
Algorithm 1 TCP-AWARE DYNAMIC ARQ ALGORITHM DESCRIPTION

1: $IF\ w_{ij}\ IS\ LESS\ THAN\ 10^4\ THEN$
   $\text{Q1} \leftarrow P_{ij}$
2: $ELSE\ IF\ w_{ij}\ IS\ LESS\ THAN\ 2 * 10^4\ THEN$
   $\text{Q2} \leftarrow P_{ij}$
3: $ELSE\ IF\ w_{ij}\ IS\ LESS\ THAN\ 3 * 10^4\ THEN$
   $\text{Q3} \leftarrow P_{ij}$
4: *ELSE DROP THE PACKET*
5: *Sort* Q1: $RTO_{i_{11}j_{11}} < RTO_{i_{12}j_{12}} < ... < RTO_{i_{1n}j_{1n}}$
6: *Sort* Q2: $RTO_{i_{21}j_{21}} < RTO_{i_{22}j_{22}} < ... < RTO_{i_{2n}j_{2n}}$
7: *Sort* Q3: $RTO_{i_{31}j_{31}} < RTO_{i_{32}j_{32}} < ... < RTO_{i_{3n}j_{3n}}$
8: *Starts Retransmission from Q1*
9: $IF\ RTO_{i_{11}j_{11}}\ OR\ RTO_{i_{21}j_{21}}\ OR\ RTO_{i_{31}j_{31}}\ IS\ LESS\ THAN\ 2 * RTT\ THEN$
   Retransmit the corresponding packet
   $ELSE$
   Retransmit $P_{i_{11}j_{11}}$
10: *Continue with Q2 and then Q3*

Simulation

- Simulation Parameter
  - Simulation Duration: 600s
  - FTP servers: 16MB file download size
  - HTTP servers: HTTP 1.1
  - Email servers: 2kB
  - TCP MSS: 1460B, Reno TCP
  - MAC buffer size: 32kB
  - MAC frame size: 320B (Fragmentation enabled)
  - Physical-Layer characteristic: OFDM (802.11a, 6Mbps)
  - Operation frequency: 5.4GHz
  - Traffic: FTP 40%, HTTP 35%, Email 25%

Simulation



- 15 wireless clients, RTT for each flow is a uniformly distributed random variable with bounds set 5ms and 100ms

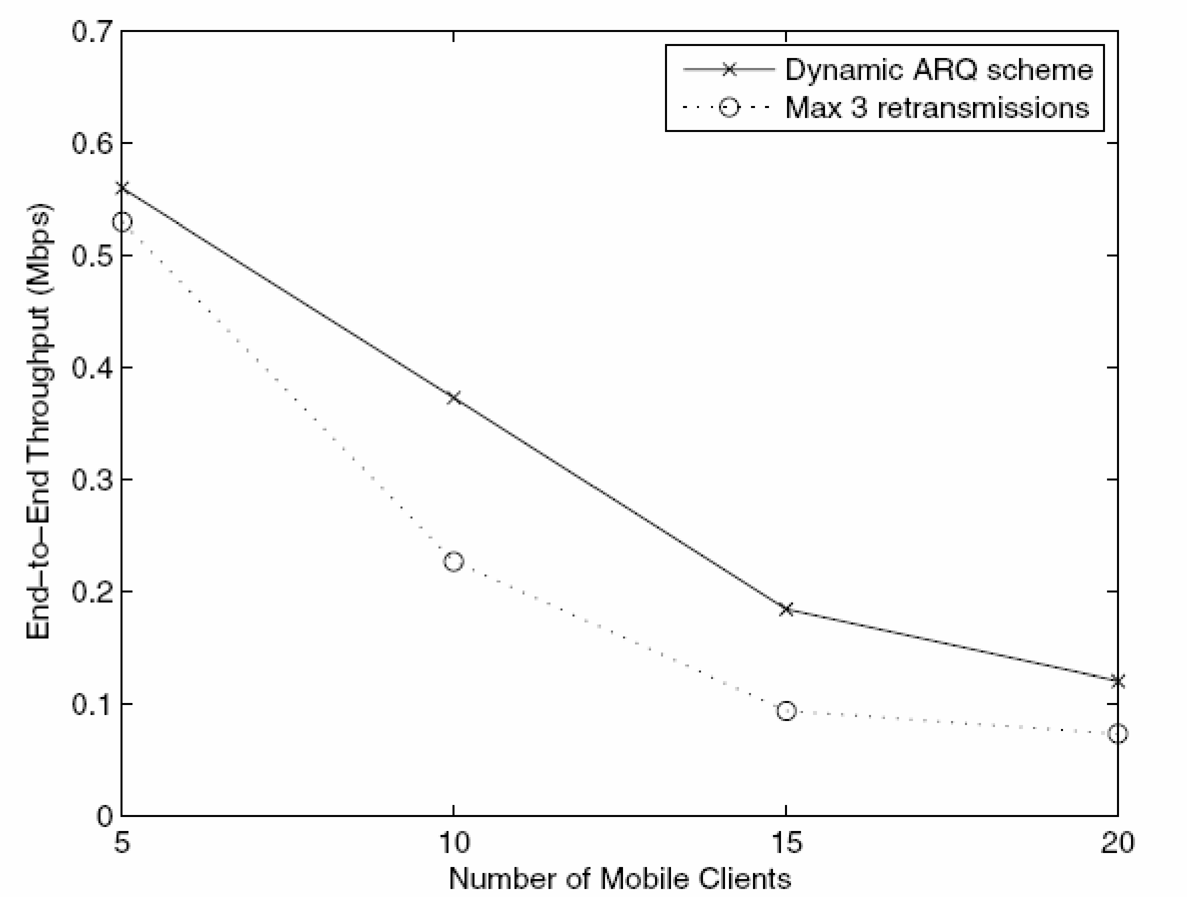
Simulation

MAXIMUM END-TO-END AGGREGATED THROUGHPUT FOR THE UNIFORM, NORMAL AND EXPONENTIALLY DISTRIBUTED RTTS

RTT Distribution	Uniform	Normal	Exponential
Throughput (kbps): Dynamic	550	560	325
Throughput (kbps): 3. Ret	280	340	275

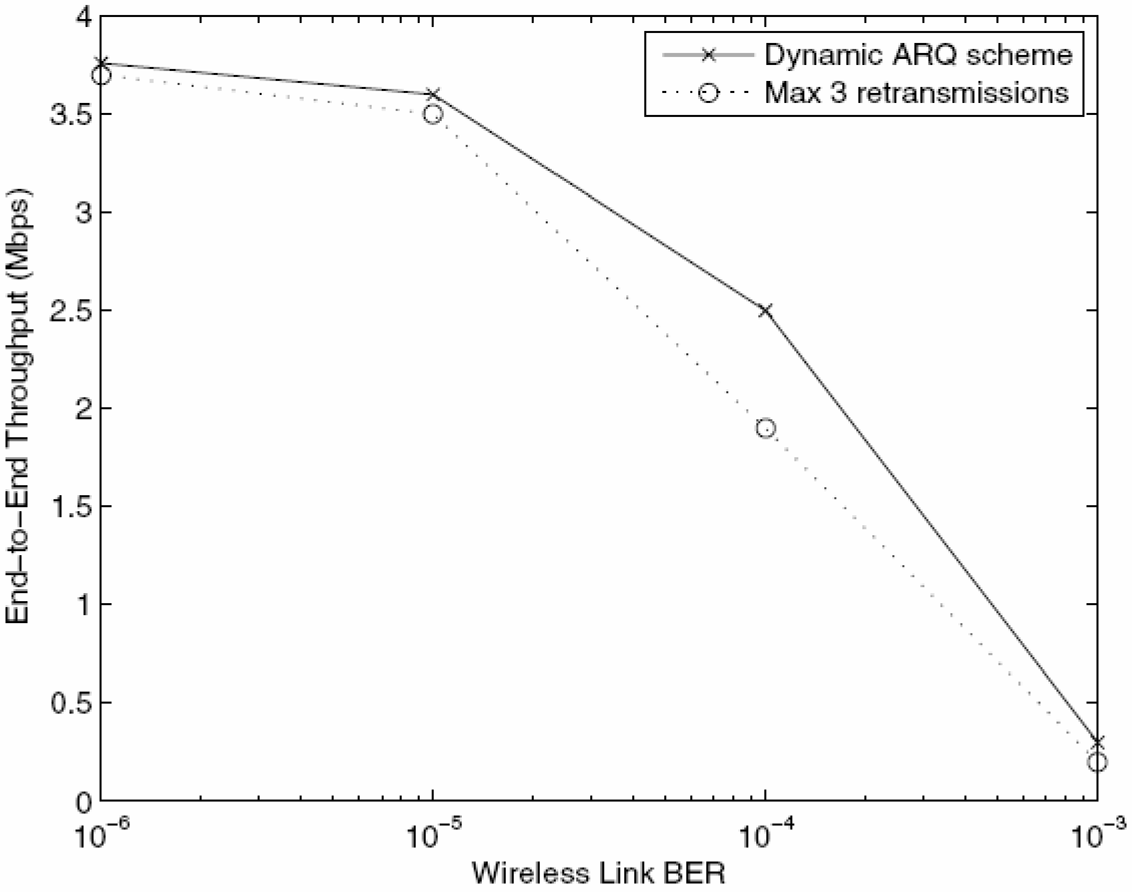
- 15 wireless clients are mobile at a fixed distance of 55m from the AP. RTTs of end-to-end path are set according to different random distributions:
  - Uniform (a = 5 ms, b = 100 ms)
  - Normal (μ = 50 ms, σ = 20 ms)
  - Exponential (β = 50 ms)

Simulation



- The third simulation scenario, using the same uniform distribution for end-to-end paths' RTTs, wireless clients are in the distance of 55m from the AP. Throughput for this scenario is plotted against the number of clients in the simulation, varied from 5 through 20.

Simulation



- 15 wireless clients, and the same RTTs for the end-to-end paths, the wireless link Bit Error Rate (BER) is increased from 10^{-6} to 10^{-3}

Simulation

AVERAGE PERCENTAGE OF TCP RETRANSMITTED PACKETS IN THE FIRST, SECOND, THIRD AND FOURTH SCENARIOS.

Simulated Scenario	1^{st}	2^{nd}	3^{rd}	4^{th}
Dynamic Scheme (ret. packets)	10%	9.7%	11.5%	10.4%
3. Ret Scheme (ret. packets)	11.6%	11.2%	13%	12%

Conclusion

- A TCP-aware dynamic ARQ algorithm has been proposed.
- The results presented in Tables 1-2 and Figs. 2-4 show a 15-60% improvement in end-to-end performance.