Buffer sizing in 802.11 Wireless Mesh Networks

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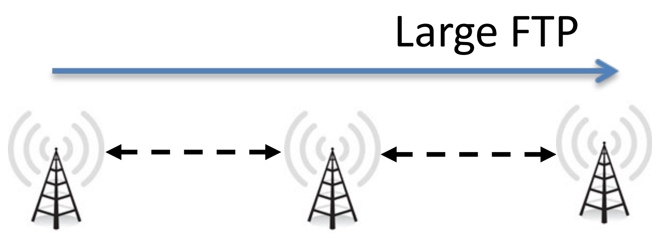
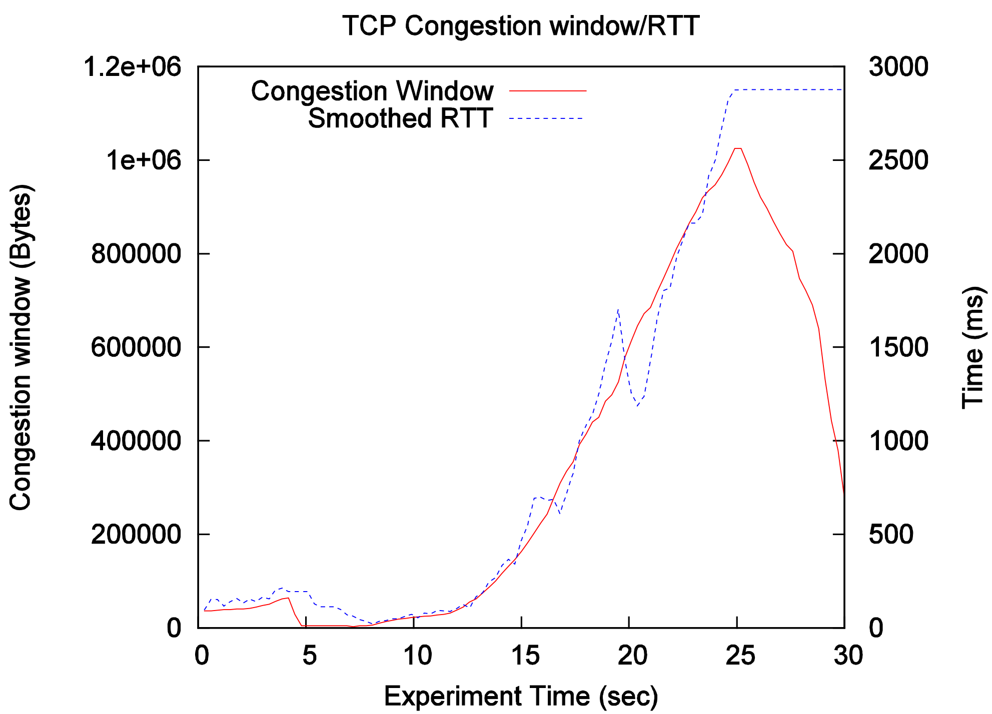
‘Bufferbloat’





Impact of large buffers

- TCP cwnd grows to fill available (large) buffers
  - Impacts TCP stability
  - Increases queueing delays for other flows sharing the buffer

Problem Statement

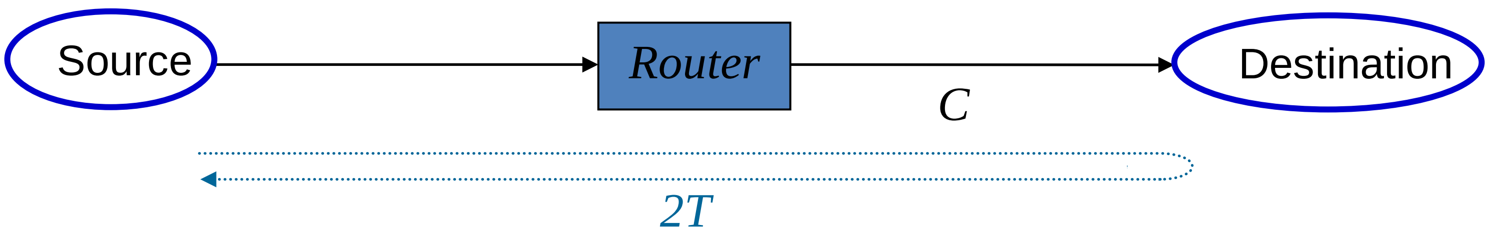
Large buffers → high throughput, high delays
small buffers → low utilization, low delays

- Determine buffer size to balance throughput & delay trade-off in WMNs

Outline

- Buffer sizing in wired networks
- Wireless challenges
- Bottlenecks and buffers in WMNs
- Performance evaluation
- Conclusions

Buffer sizing in wired networks



- Router needs a buffer size of $B = 2T \times C$
  - 2T is the two-way propagation delay
  - C is the bottleneck link capacity

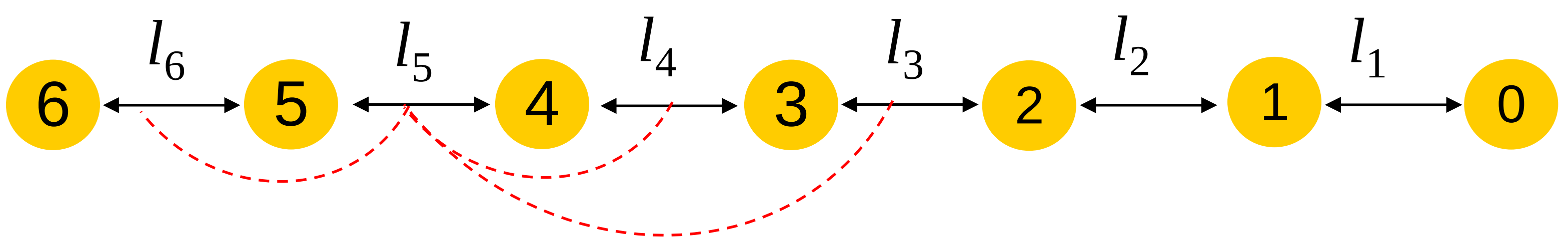
Wireless challenges

- Wireless link: abstraction for shared spectrum
  - Bottleneck spread over multiple nodes
- Variable network capacity
  - Sporadic noise and interference
  - Random MAC scheduling

Collision Domains

- Set of interfering links that contend for channel access

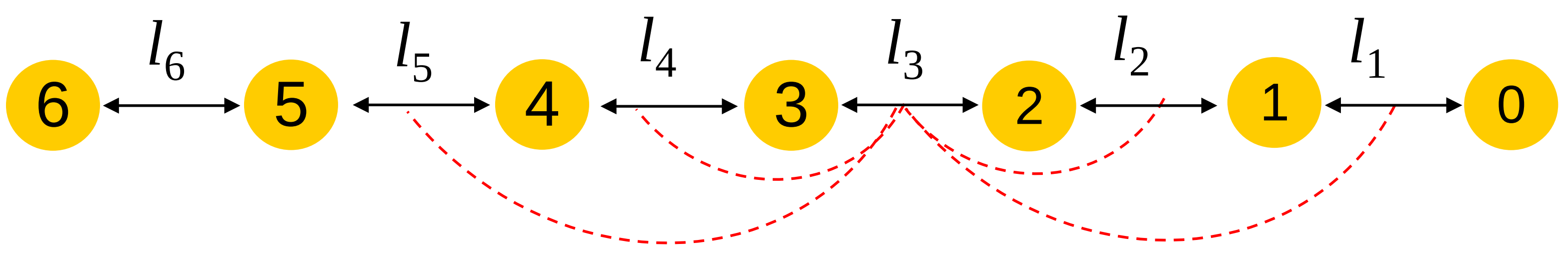
2-hop interference model: approximates RTS/CTS use in 802.11



Collision domain of link l_5

Bottleneck Collision Domain

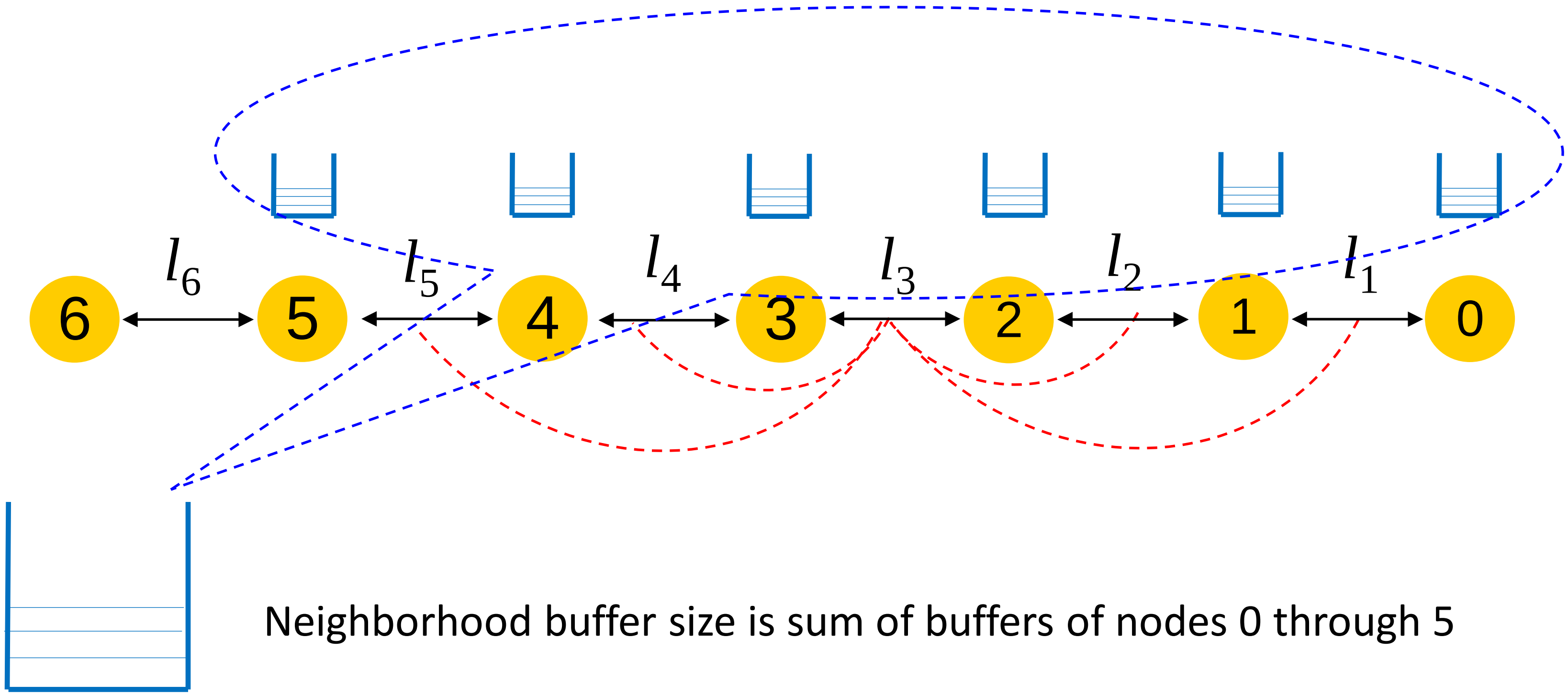
- Set of links that contend with max. no. of links
  - Limits the end-to-end rate of a flow



Collision domain of link l_3

Cumulative Bottleneck Buffers

- Sum of buffers of nodes in the bottleneck collision domain



Neighborhood buffer size is sum of buffers of nodes 0 through 5

Two part problem

1) Determine bottleneck buffer B

2) Assign b_i to nodes s.t. $\sum_{i \in \, bottleneck} b_i = B$

Step 1: Bottleneck Buffer Size

$$B = 2T \times C$$

- Bottleneck fully utilized as long as *any* node in the bottleneck has a packet to transmit
- Account for channel variations by using loose bounds on T and C values

Step 2: Per-node buffer

- Strategy 1: Equal division: $\frac{B}{\#\,nodes}$
  - But drops closer to source are preferable to drops closer to destination

Step 2: Per-node buffer

- Strategy 2: Introduces cost function s.t. cost of drop increases with hop count

$$\min \sum_{i=1}^{M} Drop\ probability \times cost\ function$$

$$\text{subject to} \quad \sum_{i=1}^{M} b_i = B$$

$$\text{and} \quad b_i \geq 0, \forall\, i \in M$$

where M is the number of nodes in the bottleneck collision domain

Step 2: Per node buffer

- If the cost of a packet drop increases linearly with hop count:

$$b_1 : b_2 : \ldots : b_M = 1 : \sqrt{2} : \ldots : \sqrt{M}$$

Performance Comparisons

- Compare with
  - Default ns-2 buffer size (50 pkts)
  - TCP with adaptive pacing (TCP-AP)
    - Space packet transmissions over a 4-hop propagation delay

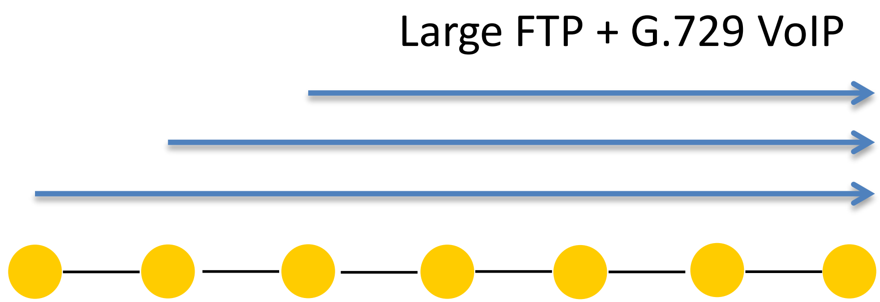
Performance Evaluation: Single flow

- Key observation: Collectively sizing buffers lead to small buffers (1-3 pkts) at nodes

Scheme	Normalized goodput	Normalized RTT
50 pkt buffer	1	20.3
TCP-AP	0.90	1
Neighborhood buffer sizing	0.96	2.2

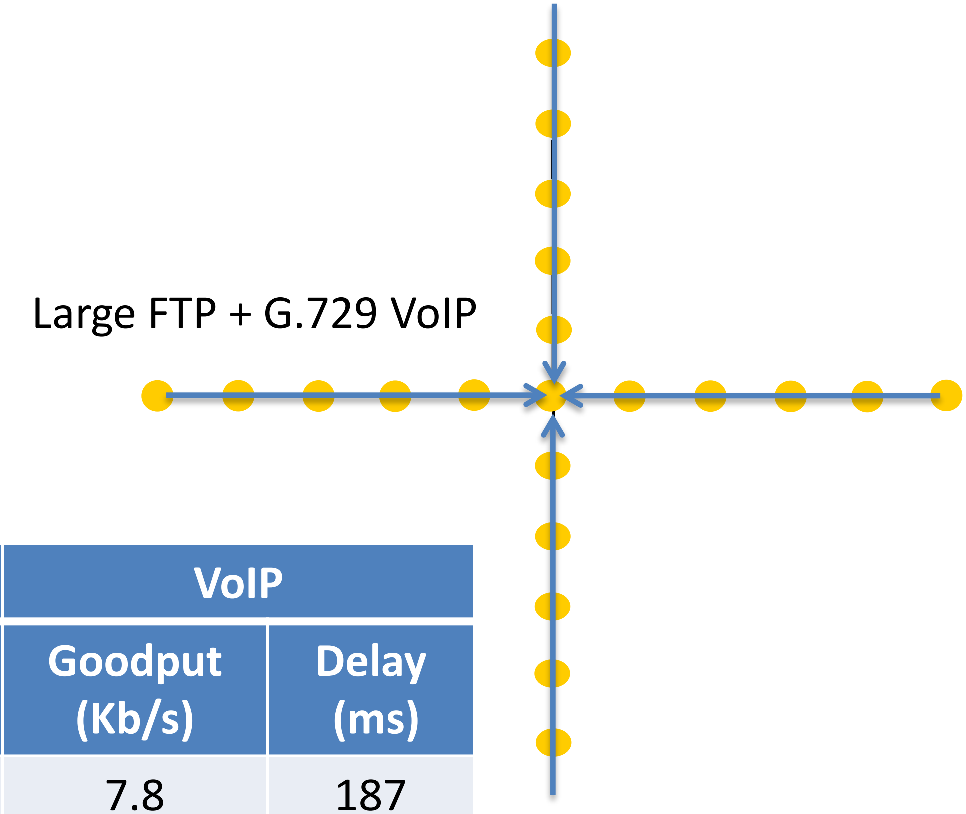
Performance statistics averaged over multiple topologies

Performance Evaluation : Multi-flows



Scheme	FTP		VoIP	
	Goodput (Kb/s)	RTT (ms)	Goodput (Kb/s)	Delay (ms)
50 pkt buffer	261	388	7.8	239
TCP-AP	240	54	8	37
Neighborhood buffer sizing	250	87	8	40

Performance Evaluation : Multi-flows



Scheme	FTP		VoIP	
	Goodput (Kb/s)	RTT (ms)	Goodput (Kb/s)	Delay (ms)
50 pkt buffer	382	300	7.8	187
TCP-AP	339	33	7.9	24
Neighborhood buffer sizing	368	71	7.9	35

Conclusions

- Shared wireless spectrum requires rethink of bottlenecks and buffers
- Propose mechanisms for sizing bottleneck buffers and distributing it among nodes
- Simulations improve RTT by 6x - 10x over plain TCP with large buffers

Questions/Comments/Feedback

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