

An Analysis of Active End-to-end Bandwidth Measurements in Wireless Networks

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Outline

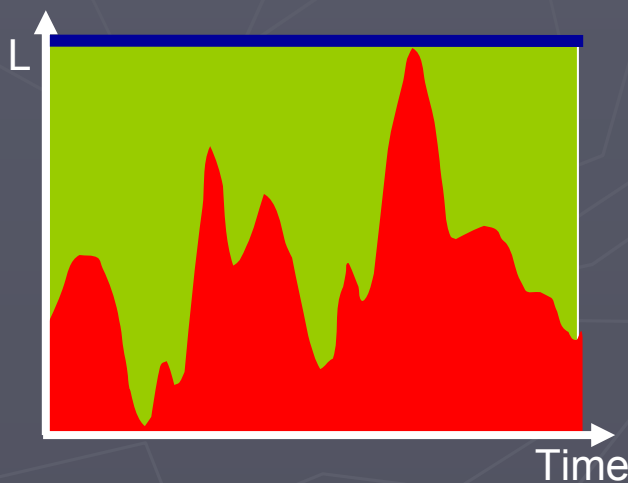
- ▶ What is available bandwidth?
- ▶ Motivation: why measure AB in wireless networks?
- ▶ TOPP model
- ▶ Experimental
 - setup
 - results
- ▶ Extension of TOPP model
- ▶ Link capacity estimation failure
- ▶ Conclusions

Available bandwidth

- ▶ Definition of available bandwidth
 - The unused portion of the link capacity during a time interval
 - End-to-end available bandwidth

▶ Available bandwidth

▶ Cross traffic



Motivation

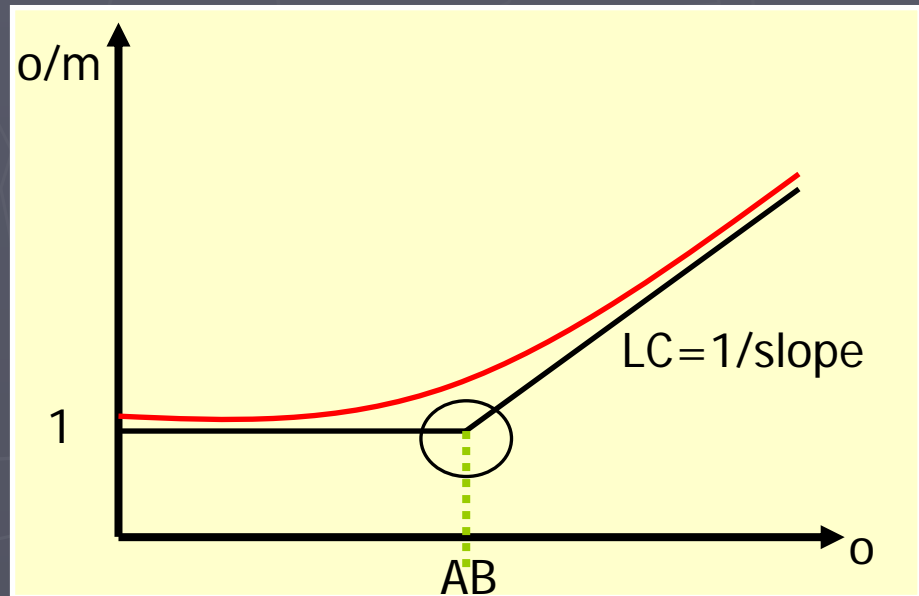
- ▶ WLAN are becoming more common
 - On the edges
 - Home/Hotspots
 - Often bottlenecks, WAN has much higher capacity
- ▶ Available bandwidth tools must estimate correctly when the bottleneck is a WLAN

The TOPP model

- ▶ To study properties of WLAN bottlenecks
 - Use the TOPP model
 - Implemented in a tool
- ▶ Asymptotic behaviour

$$m = \begin{cases} o & \text{if } o < AB \\ \frac{o}{(x+o)} L & \text{if } o \geq AB \end{cases}$$

$$\frac{o}{m} = \begin{cases} 1 & \text{if } o < AB \\ \left(1 - \frac{L-x}{L}\right) + \frac{o}{L} & \text{if } o \geq AB \end{cases}$$

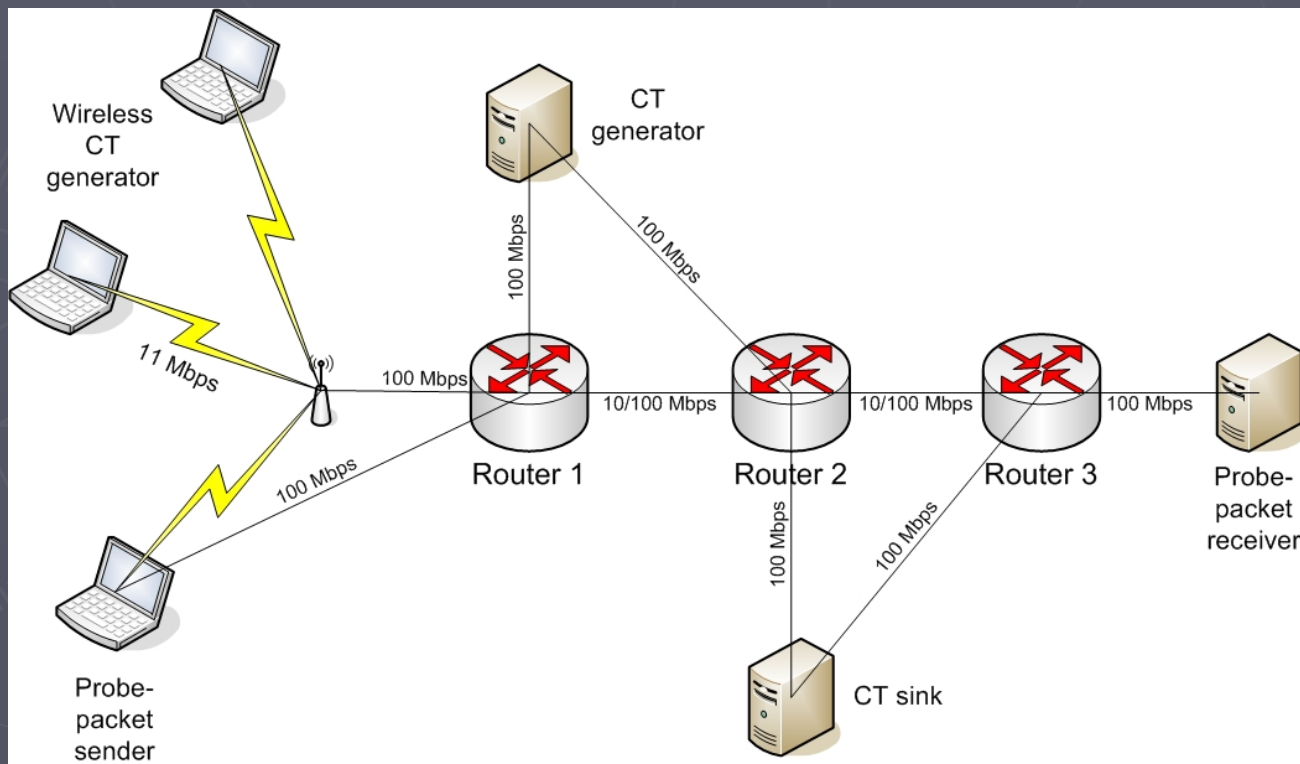


The TOPP model, cont.

- ▶ How is the rate response curve affected by WLAN bottlenecks?
- ▶ Constructed testbed
- ▶ Performed measurements

Experimental setup

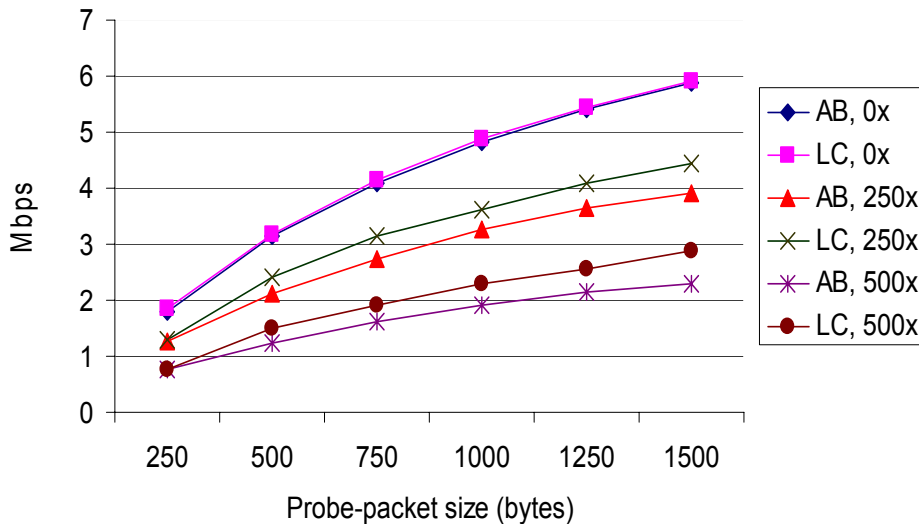
- ▶ WLAN bottleneck at the edge (11 Mbps)
- ▶ Wired links are 100 Mbps
- ▶ Cross traffic
 - Wired: approx. 10Mbps of Pareto cross-traffic
 - Wireless: varies depending on scenario



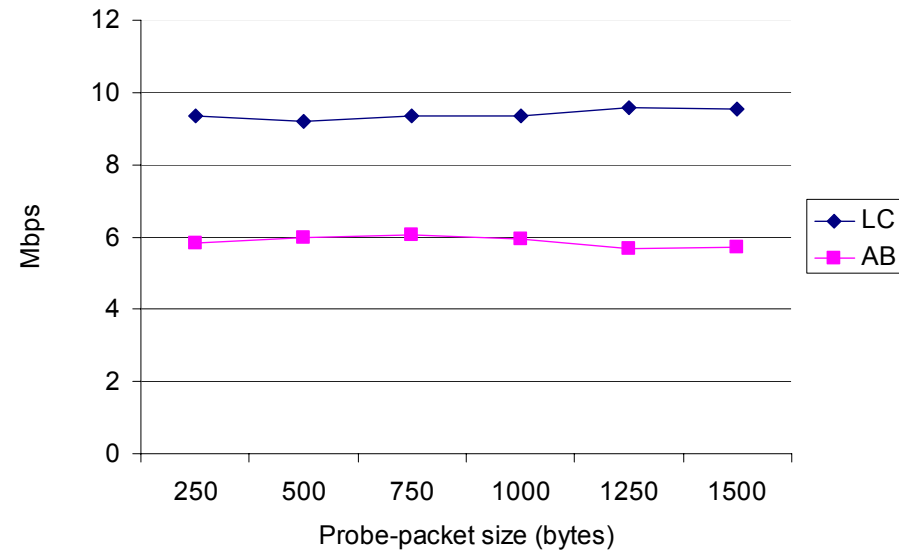
Experimental results

- ▶ Wireless
 - ▶ Constant number of probe bits
 - ▶ Top curves: 0
 - ▶ Middle - " - : 250 kbps
 - ▶ Bottom - " - : 500 kbps CBR x-traffic
- ▶ Wired
 - ▶ Constant number of probe bits
 - ▶ Top curve: link capacity; bottom curve: available bandwidth

AB and LC estimates (CBR x-traffic)



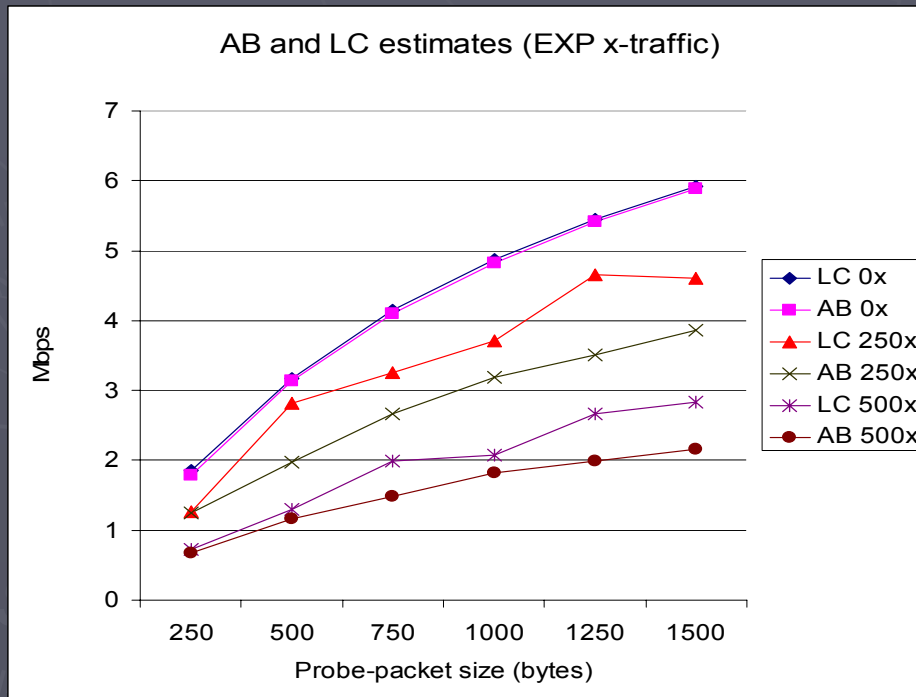
AB and LC estimates (4Mbps CBR)



Experimental results

- ▶ DietTopp results
- ▶ Top curves: 0
- ▶ Middle - " -: 250kbps
- ▶ Bottom - " -: 500 kbps EXP x-traffic

- ▶ Pathload results
 - more on this in the paper



Cross traffic	Measurement (Mbps)
0 Kbps	2.32-2.39
250 Kbps cbr	1.67-1.67
250 Kbps exp	1.73-1.73
250 Kbps par	1.40-1.63
500 Kbps cbr	0.96-0.99
500 Kbps exp	0.87-0.95
500 Kbps par	1.12-1.29

An extended TOPP model

- ▶ Need to incorporate WLAN properties into the TOPP model

$$\frac{o}{m} = \left[1 - \frac{L - x}{L} \right] + \frac{o}{L}$$

$$\frac{o}{m} = \left[1 - \frac{s/T - x}{s/T} \right] + \frac{s/t_o}{s/T}$$

$$T = T_{sifs} + T_{BO} + T_{difs} + T_{ACK} + T_s = T_k + T_s$$

- ▶ Wired

- Single-access link

- ▶ Wireless

- Link access
- Backoff
- Link-level ack

An extended TOPP model, cont.

$$\frac{o}{m} = \frac{T_k + T_s}{s} x + [T_k + T_s] \frac{1}{t_o}$$

$$\frac{o}{m} = \frac{T_k + T_s/n}{s/n} x + [T_k + T_s/n] \frac{1}{t_o/n}$$

$$\frac{o}{m} = \frac{nT_k + T_s}{s} x + [nT_k + T_s] \frac{1}{t_o}$$

- ▶ Assume sending s bits
- ▶ Changing size to s/n

An extended TOPP model, cont.

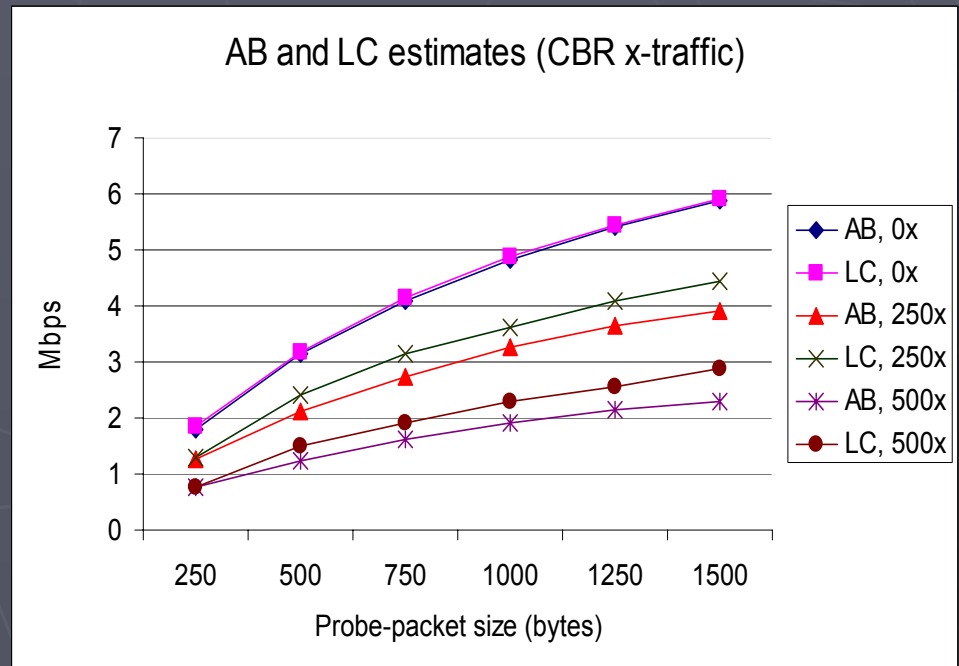
- ▶ Increased n (decreased pkt size)
 - Decreases in AB
 - Decreases in LC

- ▶ Increased T_k (increased x-traffic)
 - Decreases in AB
 - Decreases in LC

- ▶ $T_k=0$ (i.e. wired link)
 - The original TOPP model

$$\frac{o}{m} = \underbrace{\frac{nT_k + T_s}{s}}_s x + \underbrace{[nT_k + T_s]}_{LC=1/slope} \frac{1}{t_o}$$

AB=intersection LC=1/slope



Estimated vs. physical link capacity

- ▶ How can the link capacity vary?
 - The *estimate* of LC vary
 - Physical LC, the bit transmission speed, still constant (11 Mbps)
 - I.e. the TOPP model fails to directly estimate physical LC

Estimated vs. physical link capacity, cont.

- ▶ Possible to obtain the physical LC?
 - Yes, in some scenarios
 - Estimate LC with two pkt sizes, then solve

$$\begin{cases} \frac{1}{\alpha_1} = n_1 * T_k + T_s \\ \frac{1}{\alpha_2} = n_2 * T_k + T_s \end{cases}$$

$$\frac{o}{m} = \frac{nT_k + T_s}{s} x + \underbrace{[nT_k + T_s]}_{= 1 / \text{alpha}} \frac{1}{t_o}$$

- T_s gives the physical LC
- Problems due to cross traffic, T_k not constant
 - ▶ More on this in the paper

Conclusions

- ▶ Properties of WLAN
 - WLAN bottleneck properties are not the same as in wired networks
 - Affect measurement results produced by our implementation of TOPP
- ▶ Extended the TOPP model
- ▶ Discussed the relation between estimated and physical LC

Questions

