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On Evaluating a New Class of Available Bandwidth Methods

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Outline

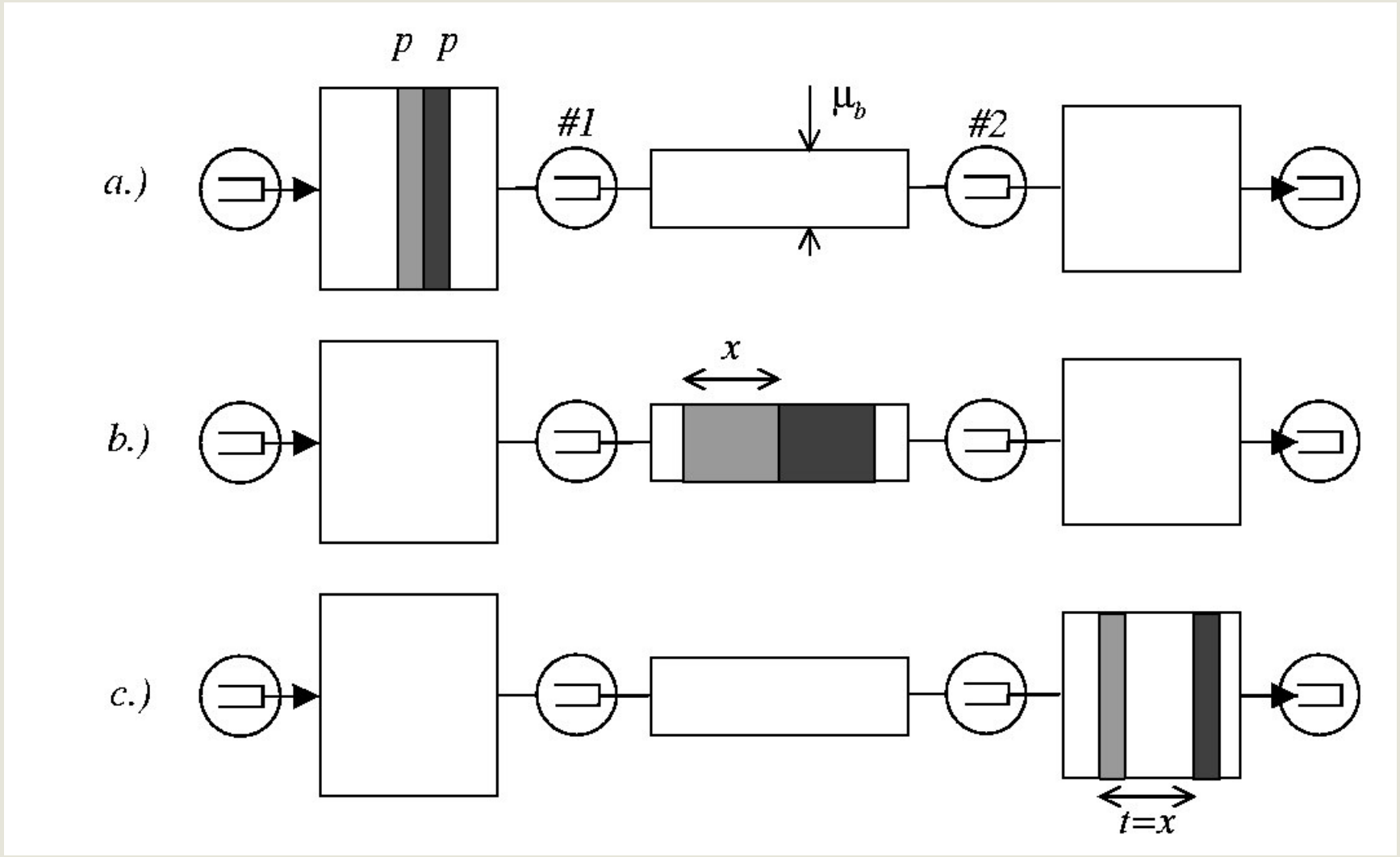
- A new class of active probing methods:
  the ‘Interaction class’
- A methodology to evaluate, compare and develop active probing methods
- Some results
- Ongoing work and future plans

Fundamental Network Effects

- Two fundamental network effects identified in the literature as the bases of existing probing techniques
  - **Spacing effect**
    - bottleneck spacing determining the inter arrival-time to the receiver
    - assumes probes being in the SAME busy period at the link of interest
  - **Accumulation effect**
    - packet size dependence of service time
    - assumes probes being in DIFFERENT busy periods at all hops

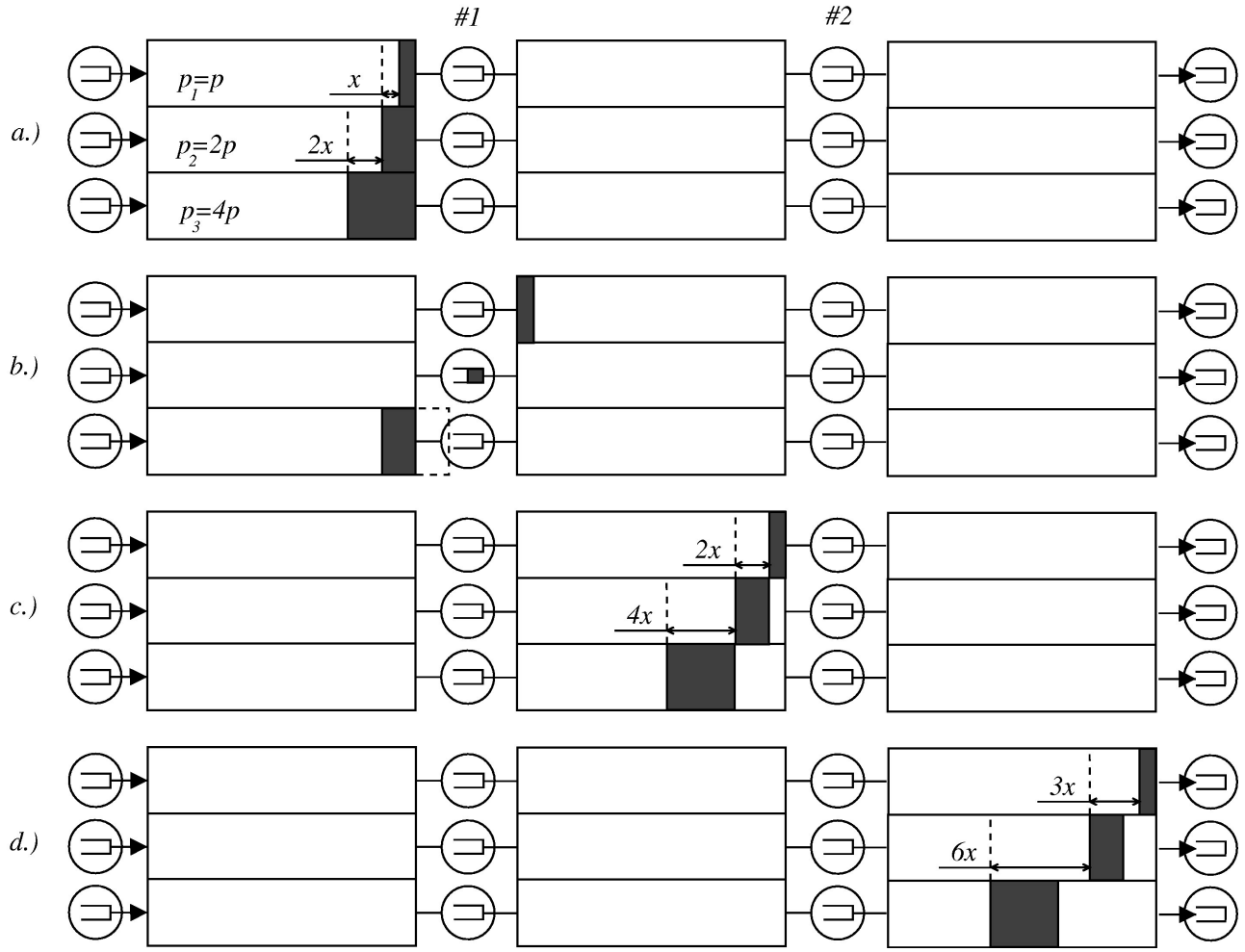
Spacing Effect

$t = p / \mu_b$



Accumulation effect

$$d_1 - d_2 = (p_1 - p_2)\Sigma_i (1 / \mu_i)$$



Existing Bandwidth Estimation Methods

- Packet Pair and Packet Trains
  - Spacing effect based
  - Probes of the pattern in the same busy period
- One Packet Based
  - Accumulation effect based
  - Well separated, independent probes
- Hybrid
  - Based on spacing and accumulation effects
  - Some probes of the pattern are designated to be in the same busy period, some to be separated

CROSS TRAFFIC TYPICALLY CONSIDERED AS NOISE

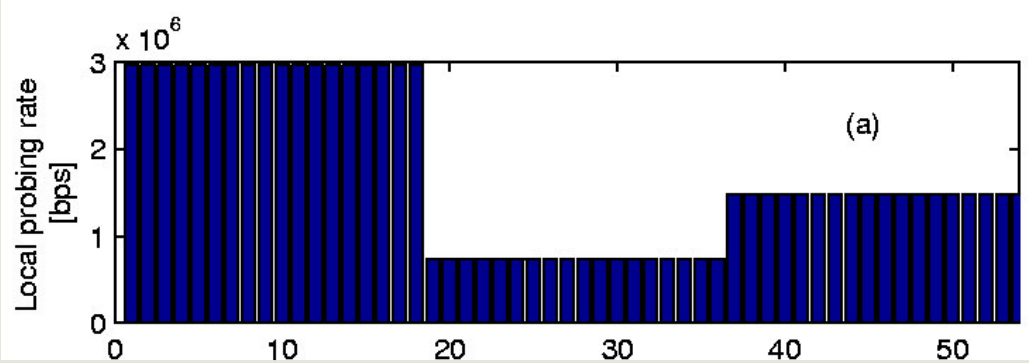
Existing Bandwidth Estimation Methods

- Other methods – the 'Interaction class'
  - Based on the interaction of cross traffic and probes
  - The cross traffic determines which probes of the pattern join the same busy period
  - The focus of these methods is to detect when and which probes join the same busy period, to detect the transition from an *independent system* to a *linear system*

CROSS TRAFFIC IS THE SIGNAL

Methods of the ‘Interaction’ class

- TOPP (Melander et.al)
- Pathload (Dovrolis et.al)



Methods of the ‘Interaction’ class

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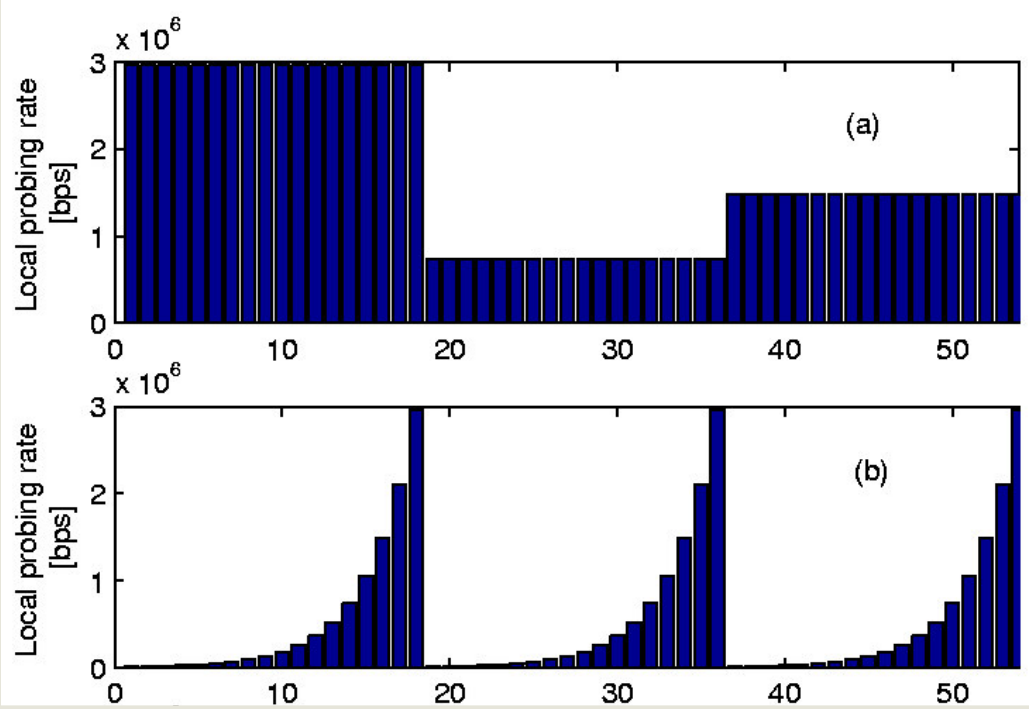
- Pathchirp (Ribeiro et.al)
- ‘(Poly)Chirp’



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- TOPP (Melander et.al)
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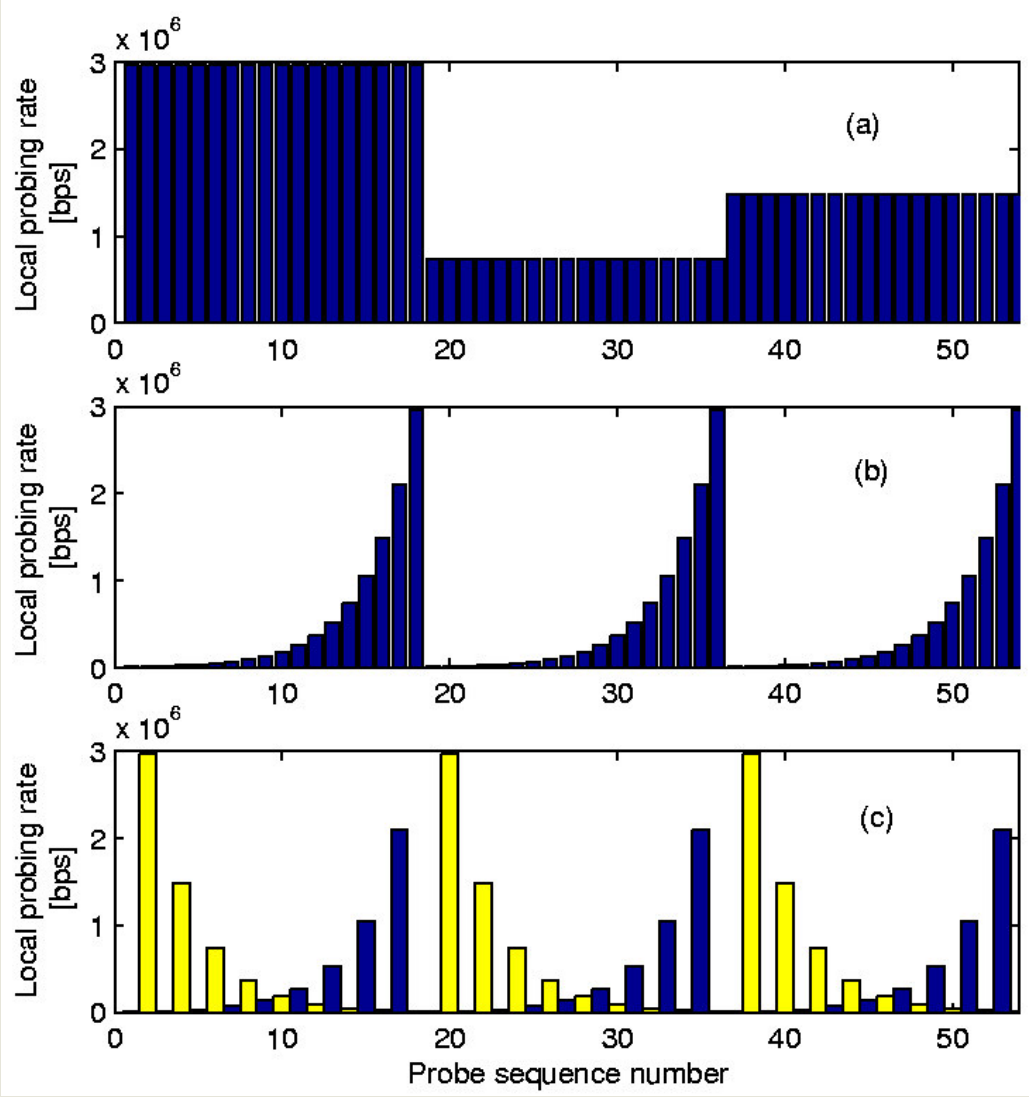
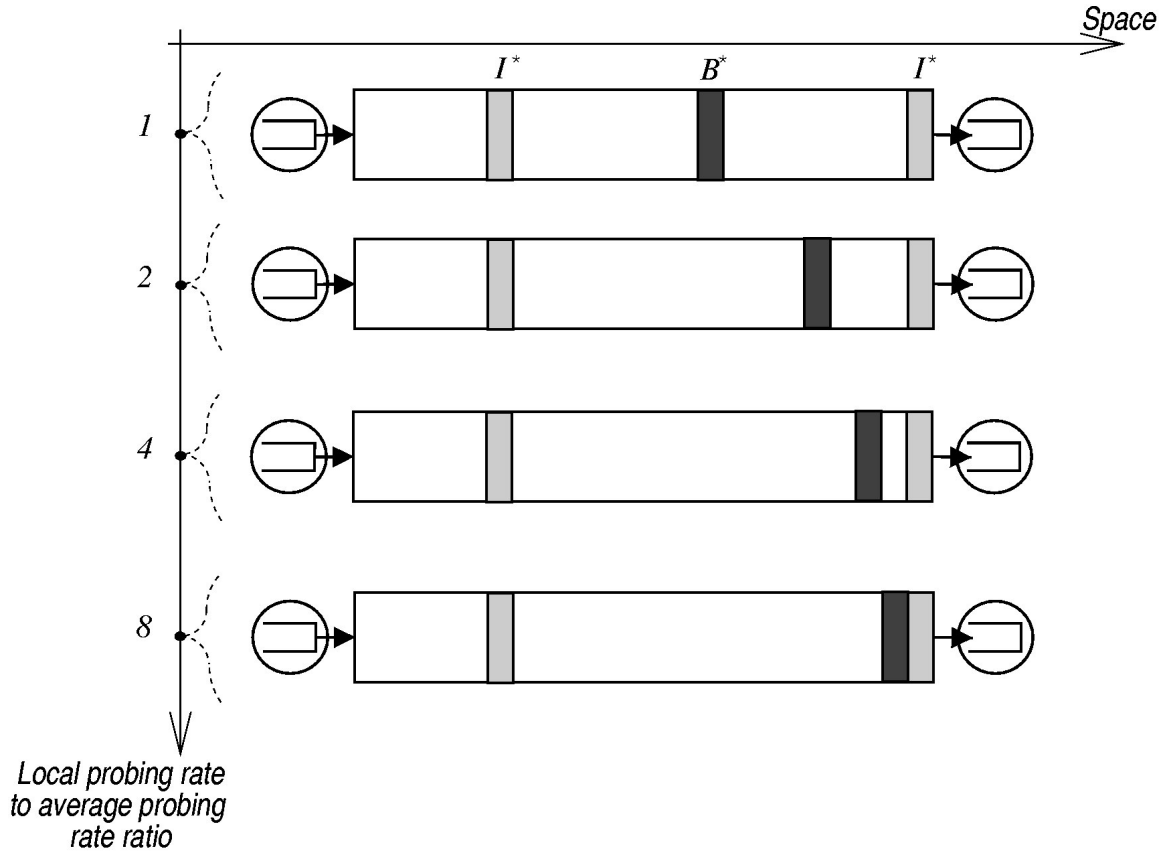
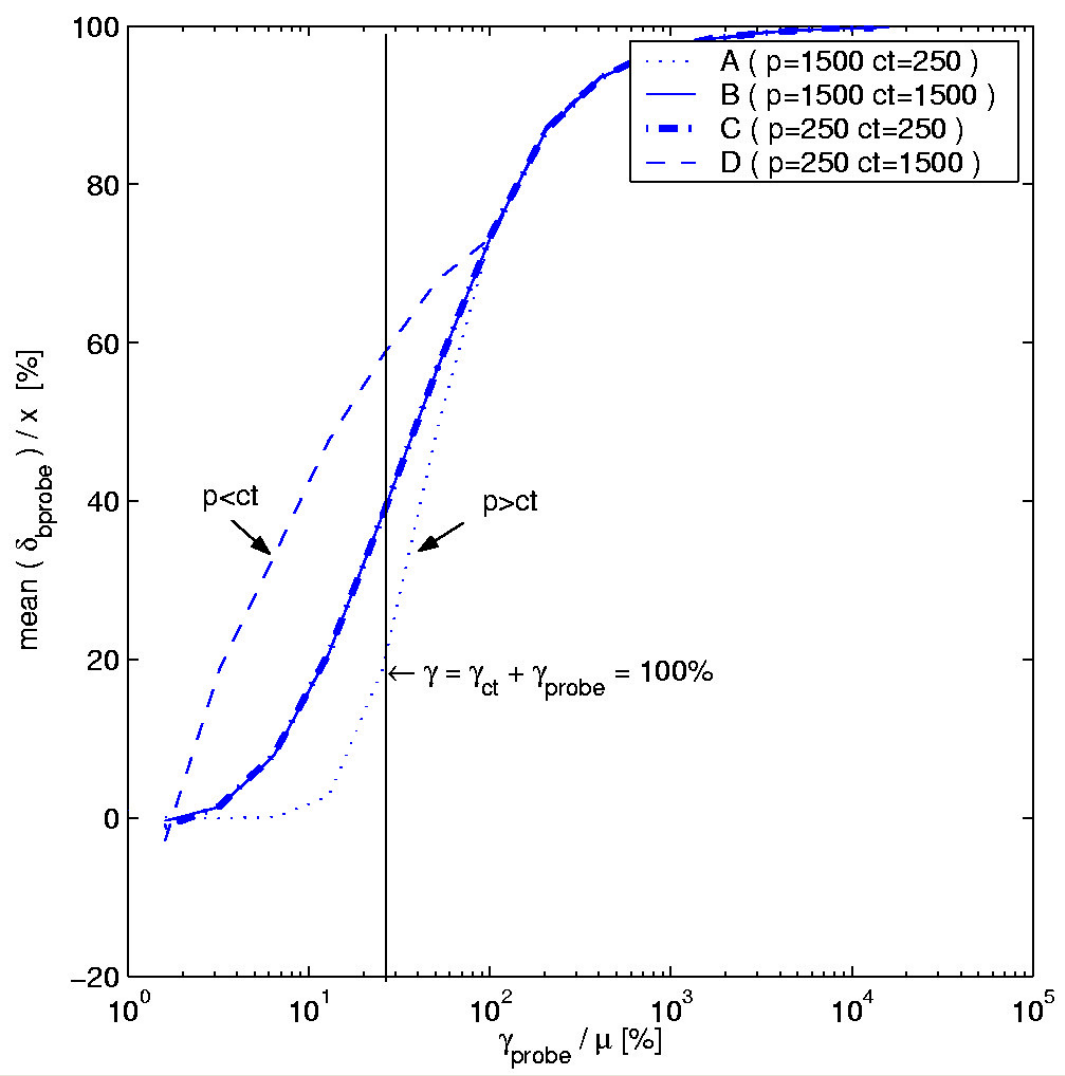
- ‘(Poly)S(moothed)chirp’



Transition from an Independent System to a Linear System



Transition – Key to the Other Methods



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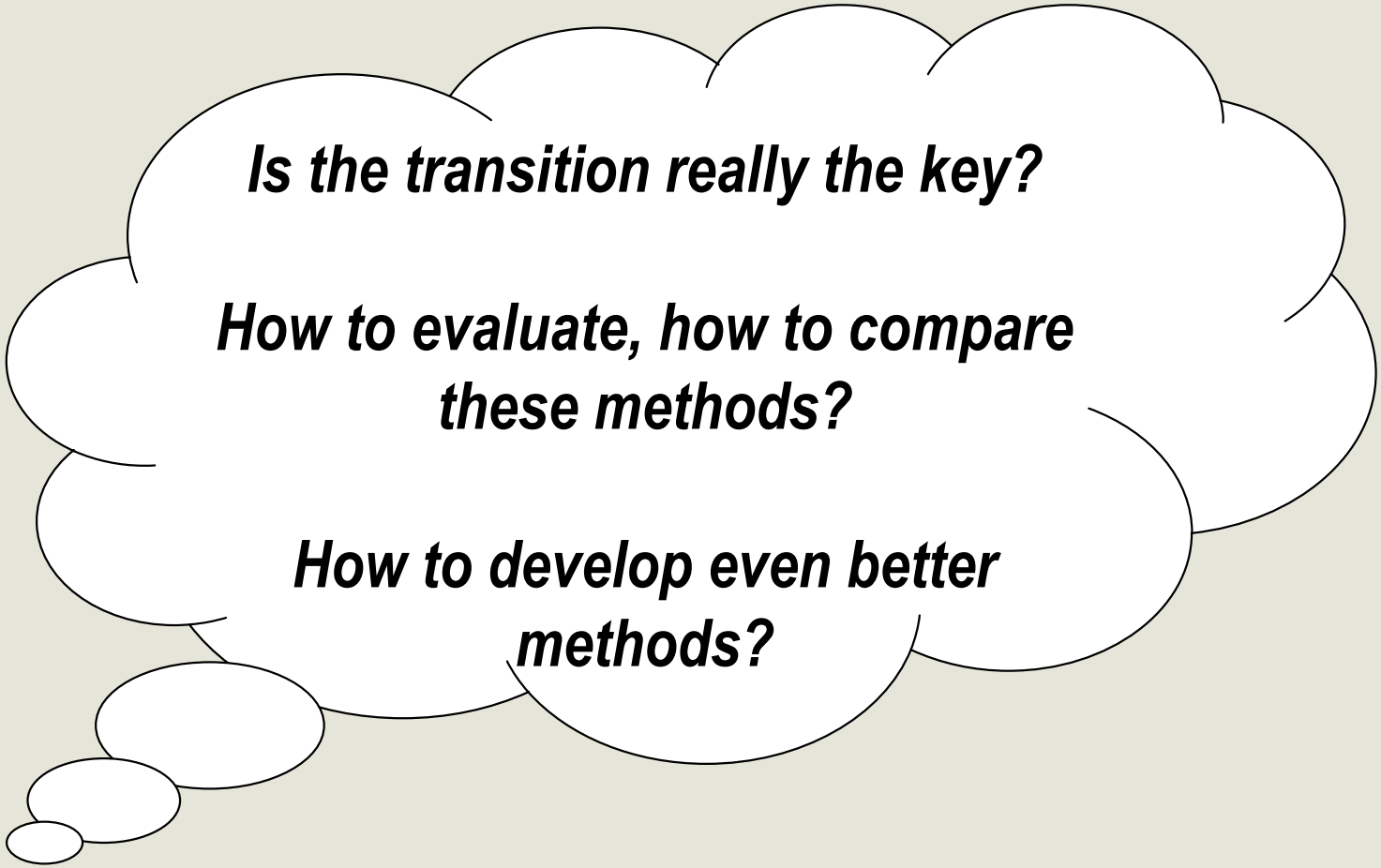
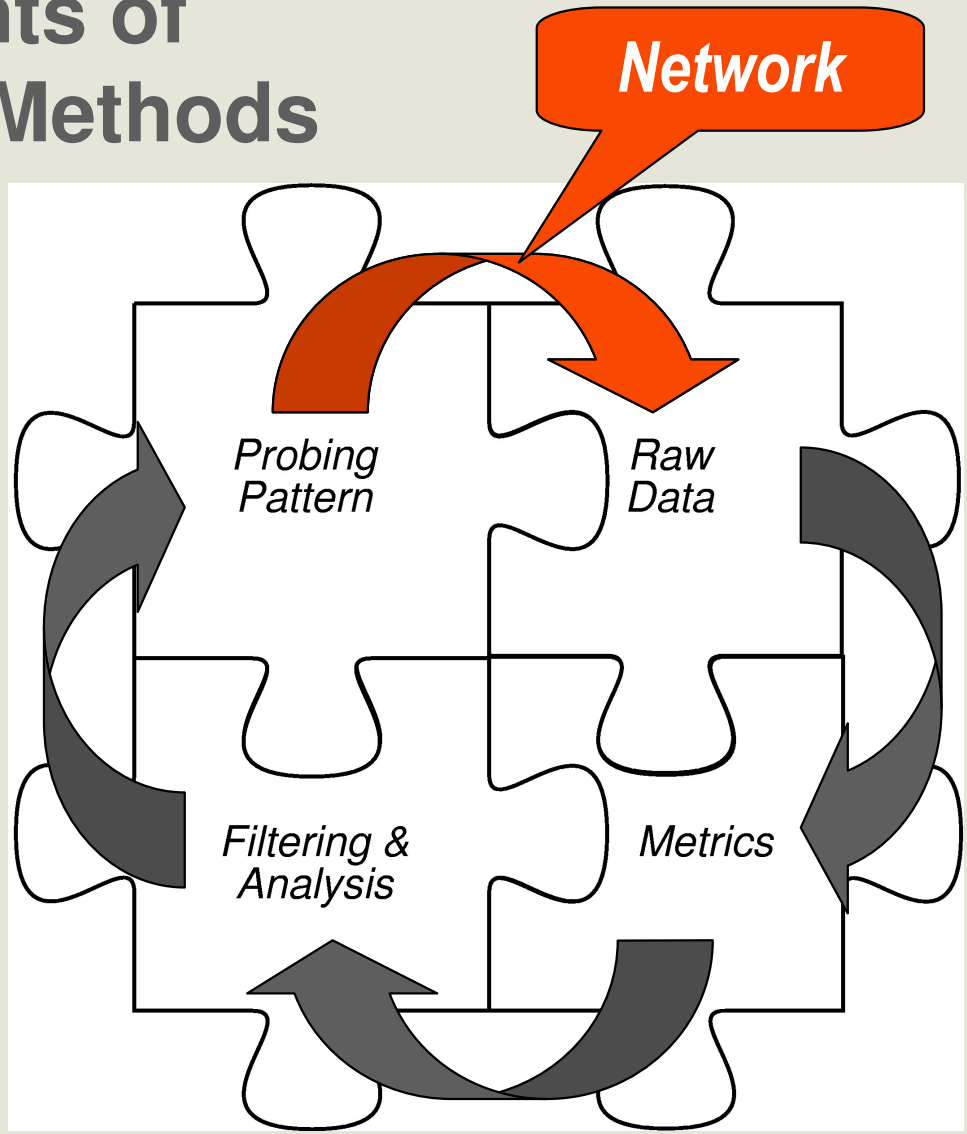
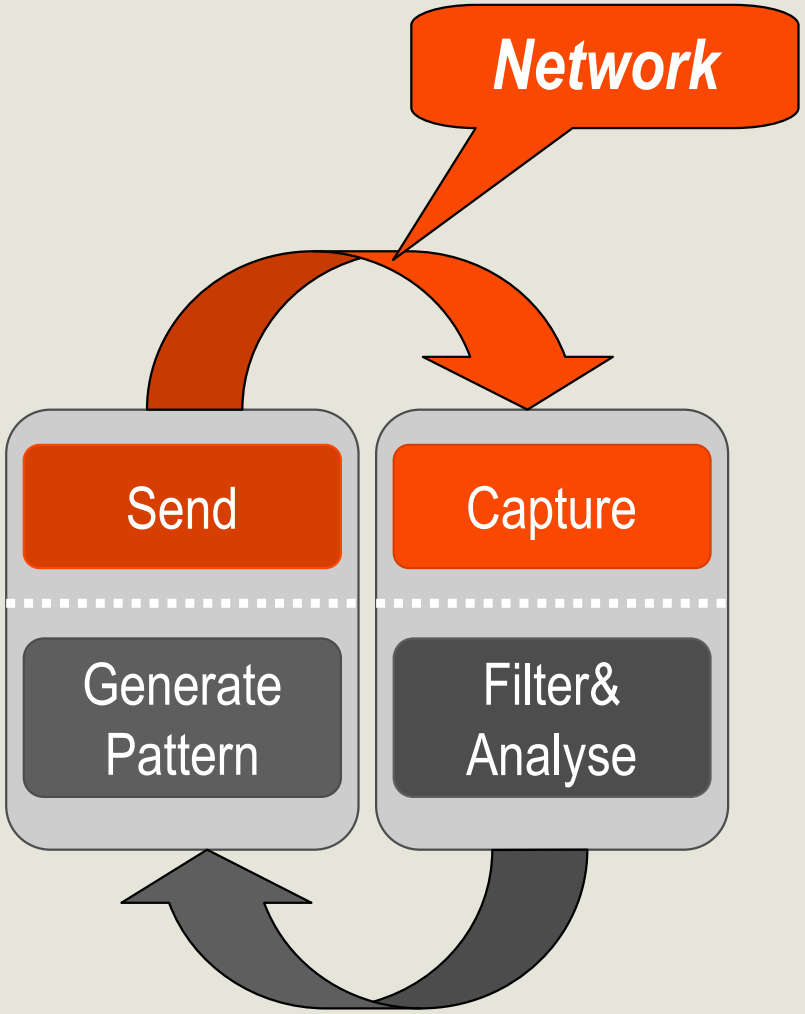


The Key Elements of Active Probing Methods



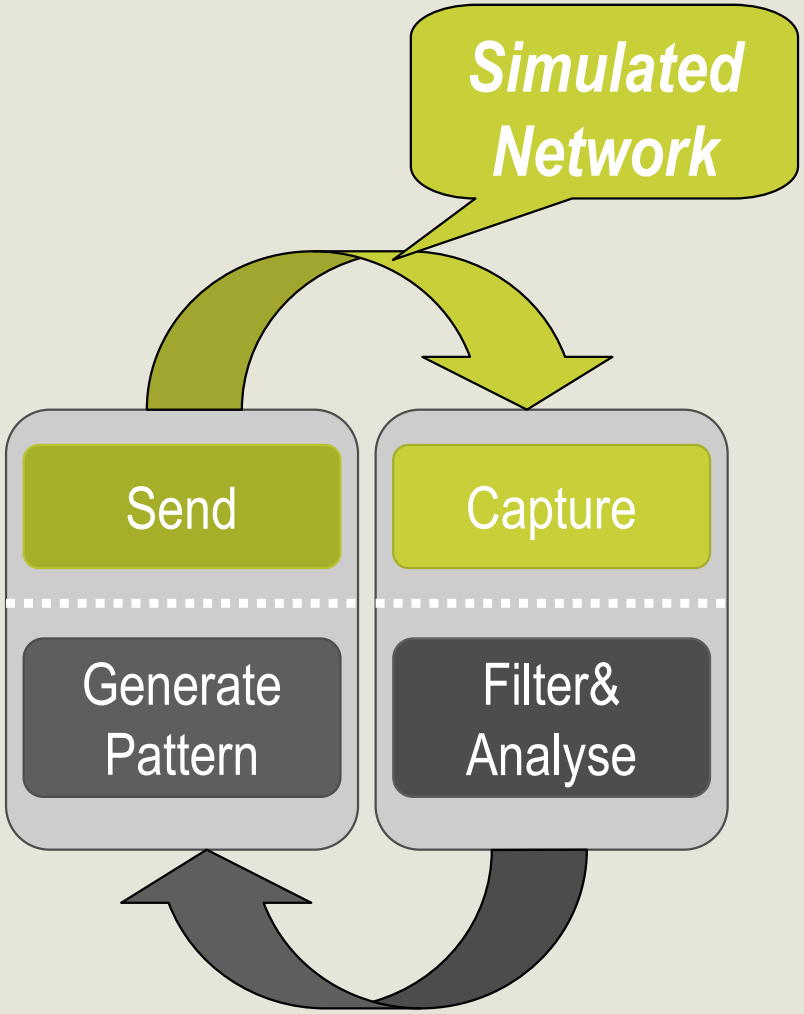
Problems of Studying Active Probing Methods

- The Network is typically
  - not fully known, neither the background traffic, nor the topology
  - not under our control
- Consequences:
  - difficult to verify the results
  - hard to repeat the experiments
  - problematic to reliably compare different methods



Studying Active Probing Methods

- The Simulated Network is
  - fully known, including the background traffic and the topology
  - “fully instrumented”
  - fully under our control
- As a consequence it is easy to:
  - verify the results
  - repeat the experiments
  - reliably compare different methods
- Essential to ensure, that the topology and background traffic is realistic

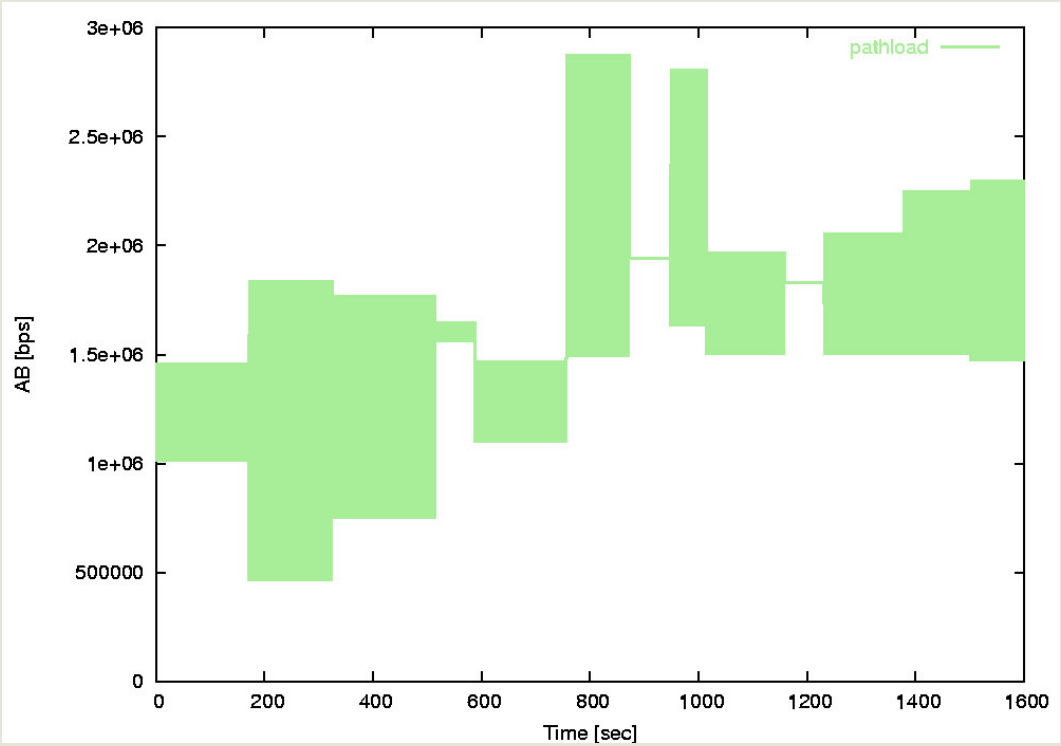


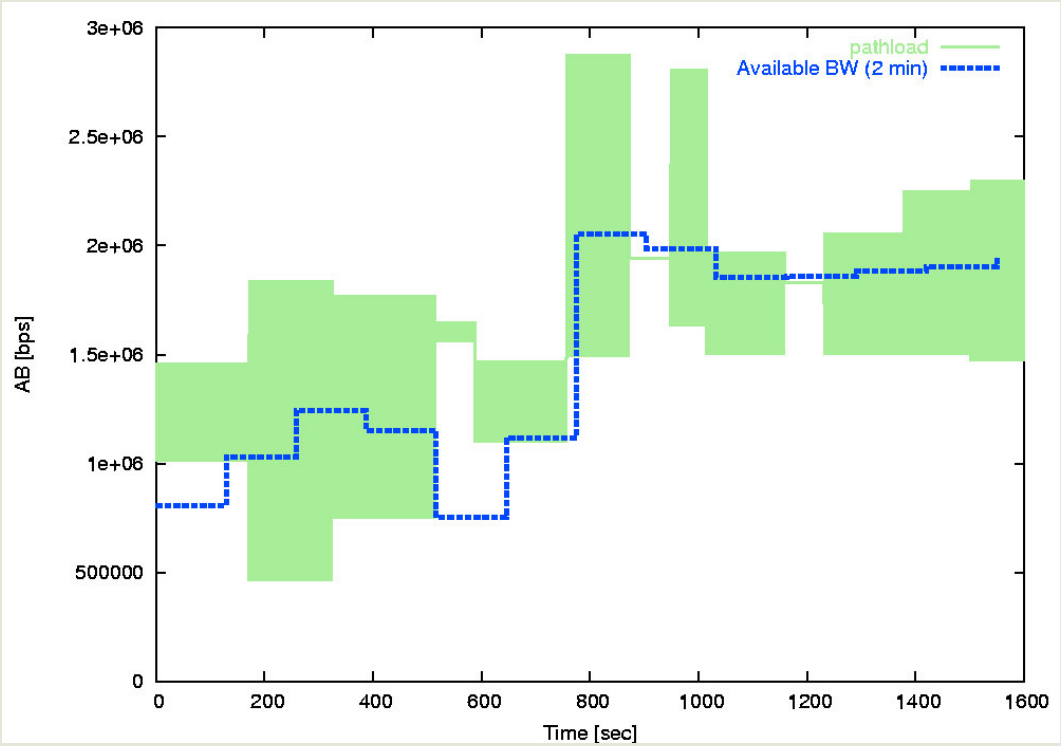
PSIM - The Probing Simulator

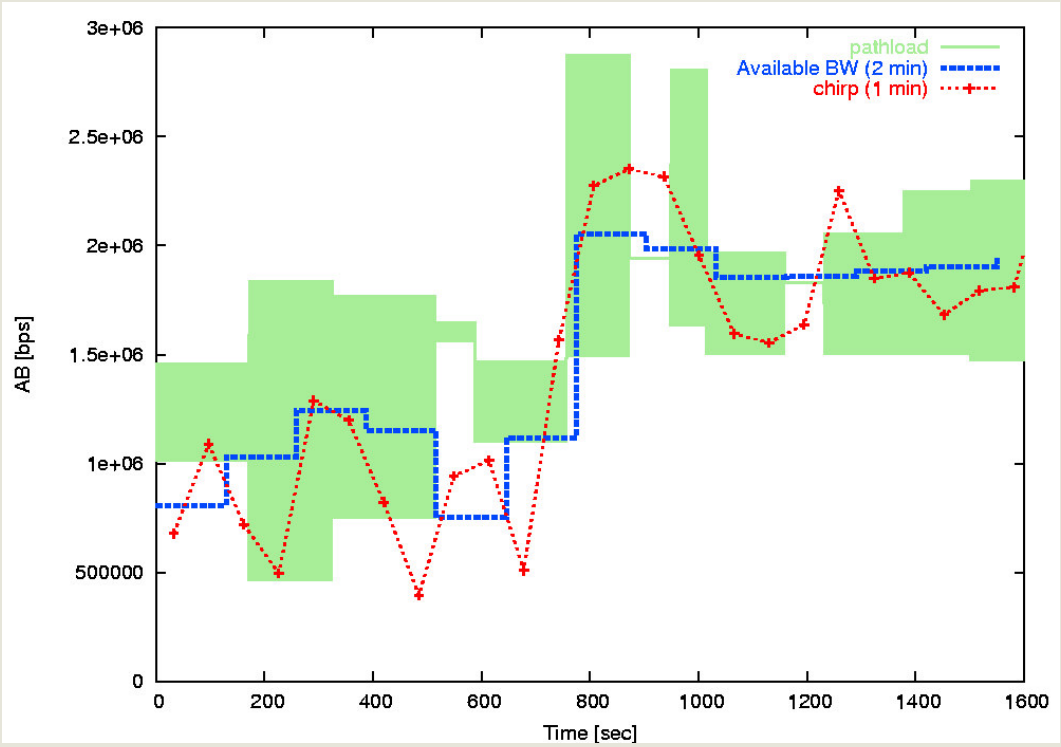
- High performance, tailored to the requirements of active probing
- A multiple hop network model – series of FIFO queues and links
- Inputs:
  - Route configuration
  - Cross traffic entering at different hops
  - Probe stream injected
- The output is the probe arrival time series to the intermediate hops and to the receiver, including information about probes being I/B
  - Calculated using the recursion relations of queueing theory
- Accepts arbitrary cross traffic – generated synthetically or from real network traces
- Compatible input/output formats with our active probing applications
  - Allowing easy switching between simulated and real network experiments

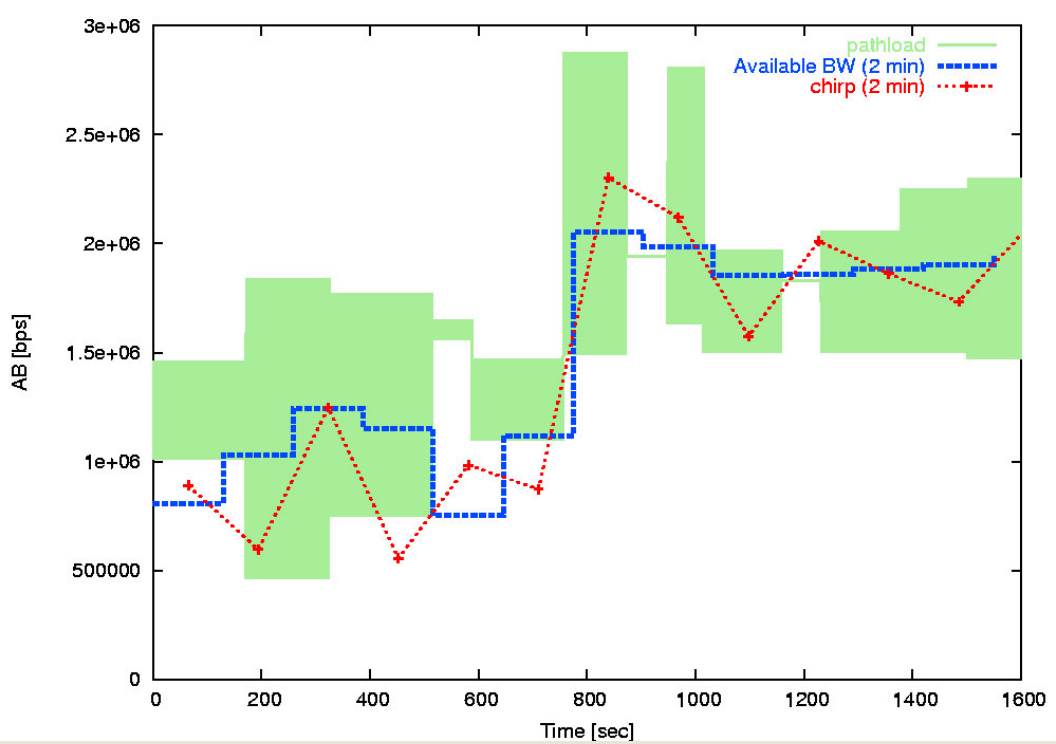
An experiment using PSIM

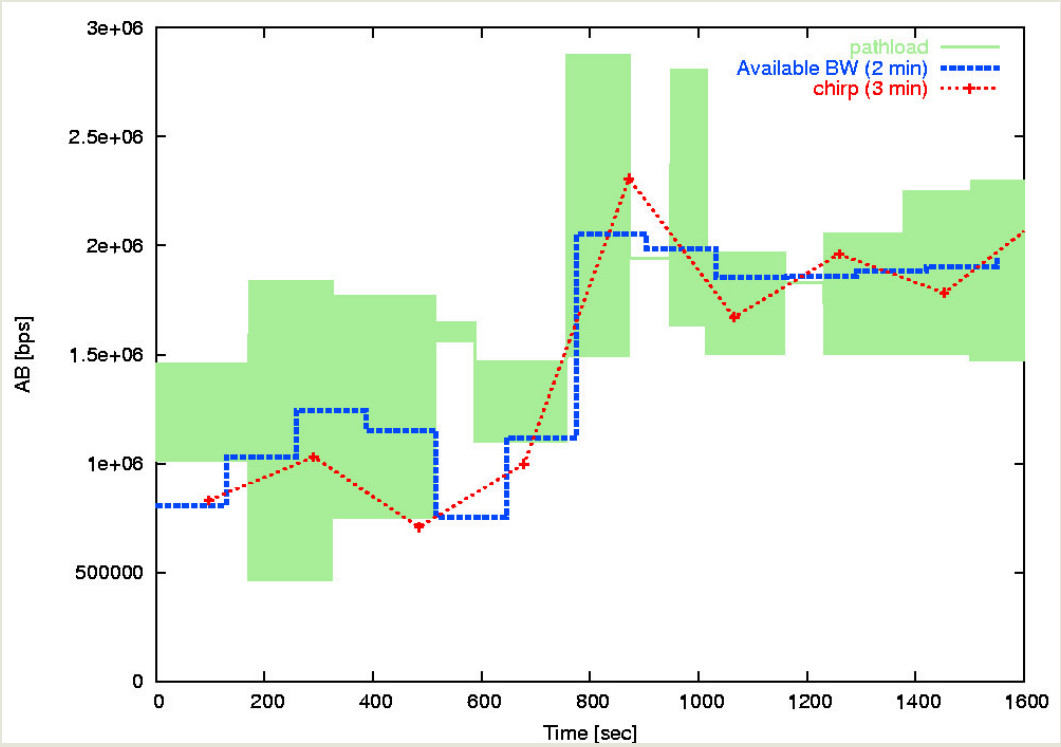
- We have integrated pathload into our framework
- Compare it to our chirp pattern based AB estimation method
- A two hop route - a100Mbps link followed by a 3Mbps link
- A 30 min long cross traffic trace
- Pathload is probing with 220 kbps average rate
- The chirp based method is probing with 42 kbps rate

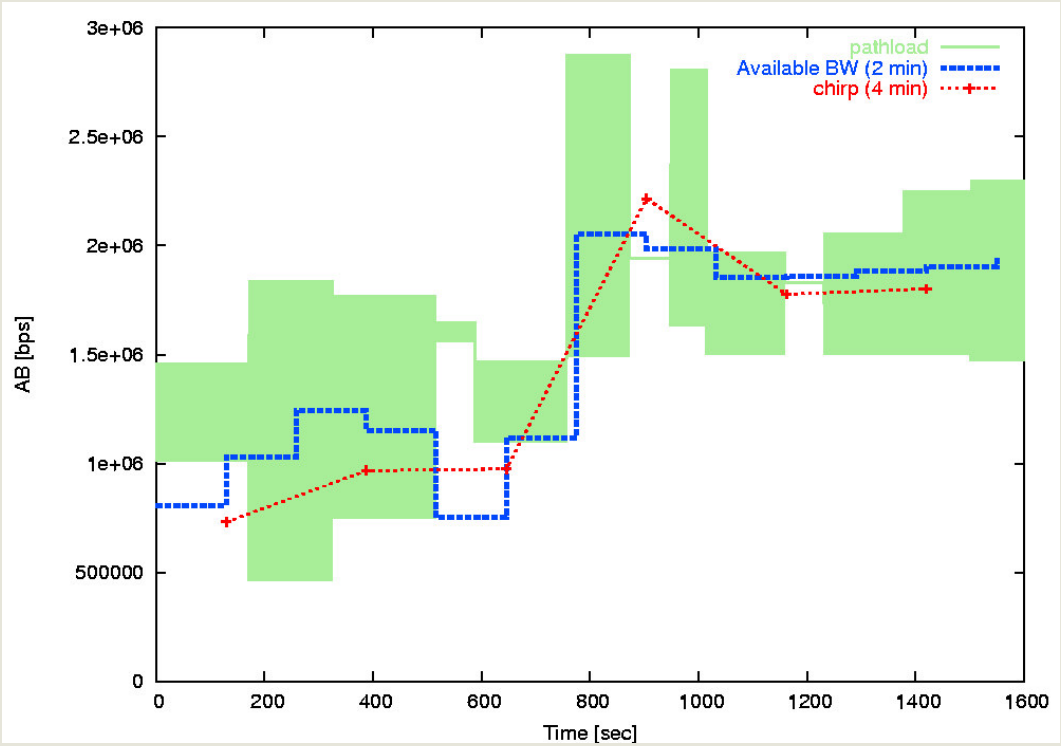

pathload
AB [bps]
Time [sec]
3e+06
2.5e+06
2e+06
1.5e+06
1e+06
500000
0
0
200
400
600
800
1000
1200
1400
1600

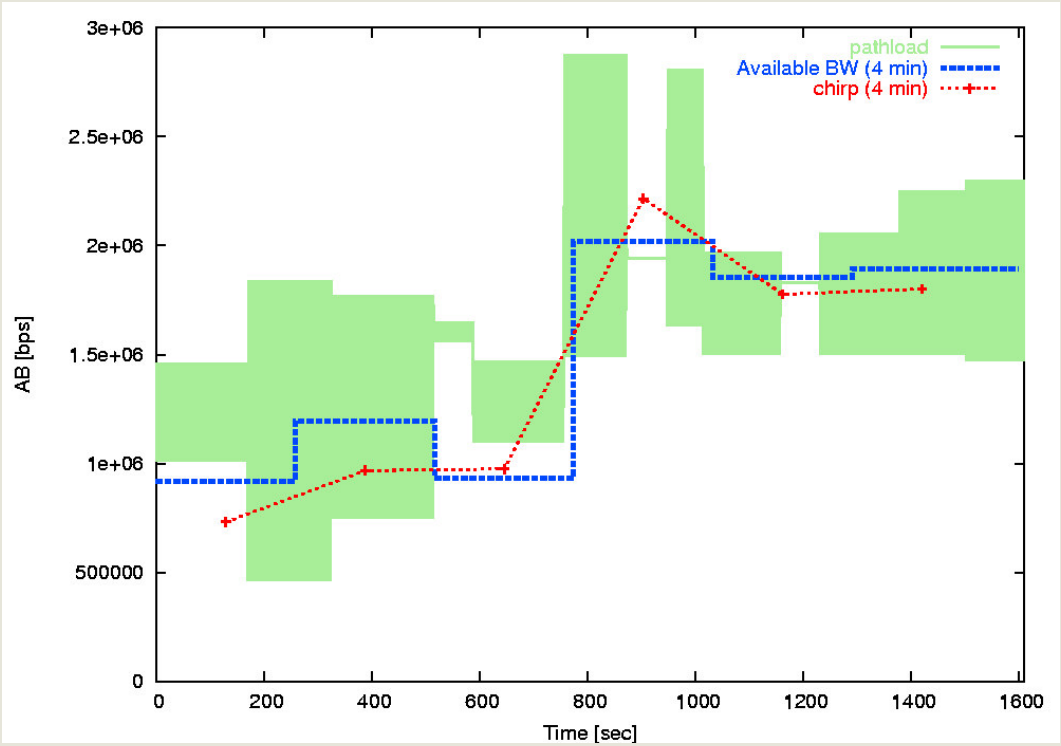

pathload
Available BW (2 min)
AB [bps]
Time [sec]
3e+06
2.5e+06
2e+06
1.5e+06
1e+06
500000
0
0
200
400
600
800
1000
1200
1400
1600


pathload
Available BW (2 min)
chirp (1 min)
AB [bps]
Time [sec]
3e+06
2.5e+06
2e+06
1.5e+06
1e+06
500000
0
0
200
400
600
800
1000
1200
1400
1600


pathload
Available BW (2 min)
chirp (2 min)
AB [bps]
Time [sec]
3e+06
2.5e+06
2e+06
1.5e+06
1e+06
500000
0
0
200
400
600
800
1000
1200
1400
1600


pathload
Available BW (2 min)
chirp (3 min)
AB [bps]
Time [sec]
3e+06
2.5e+06
2e+06
1.5e+06
1e+06
500000
0
0
200
400
600
800
1000
1200
1400
1600


pathload
Available BW (2 min)
chirp (4 min)
AB [bps]
Time [sec]
3e+06
2.5e+06
2e+06
1.5e+06
1e+06
500000
0
0
200
400
600
800
1000
1200
1400
1600


pathload
Available BW (4 min)
chirp (4 min)
AB [bps]
Time [sec]
3e+06
2.5e+06
2e+06
1.5e+06
1e+06
500000
0
0
200
400
600
800
1000
1200
1400
1600

The proof of the pudding …

- The simulation environment is not identical to the reality
  - SW and HW limitations of the probing equipment
  - Some properties of real networks may differ from the simulated model
- Ongoing and future work:
  - Integrating pathchirp into our experimental framework
  - Study of the properties of the ‘interaction class’
  - Development of a new standalone available bandwidth estimation application

Chirp based probing