Wireless Networking Projects

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The Maryland Information and Network Dynamics Lab

Participants

- Ashok Agrawala
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- Students
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  - …

Activities

- WLAN Location Determination
  - Horus Technology
  - Nuzzer Technology for passive determination of location
- Energy Efficient On-Demand Routing
- Enhancements of BEB in 802.11 in Noisy Environment
- Traffic Characterization- 802.11b MAC layer
- Z-Iteration Time-Step Simulation

Location Determination
Horus Technology

- Signal-Strength (RSSI) Based Approach

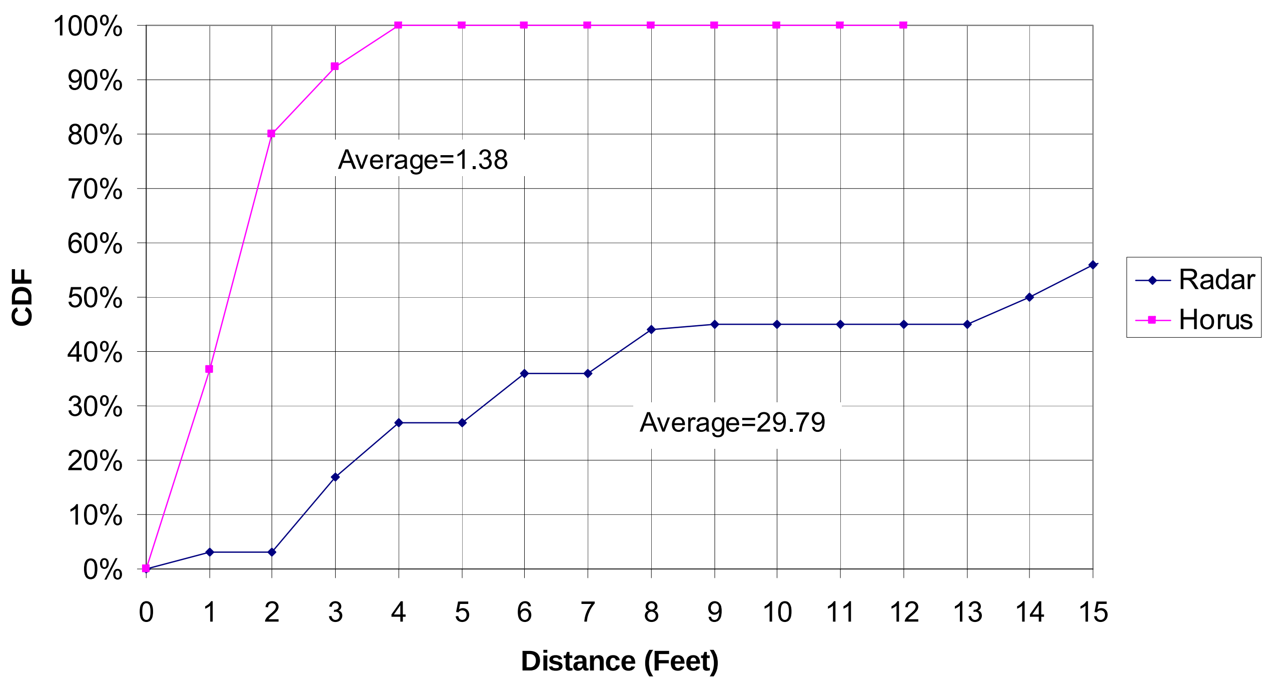
- A few commercially available, e.g. Ekahau, PanGo
- A few research groups working on it

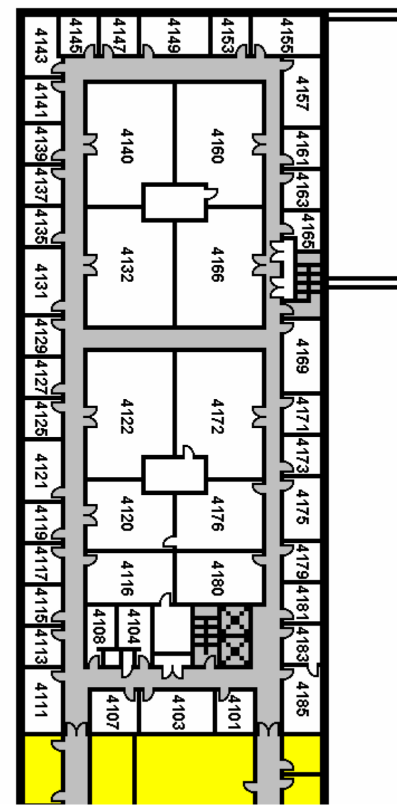
- Horus results significantly better than all

- Licensed by Fujitsu and deployed in a shopping center application

Horus

Comparison With Other Systems: RADAR





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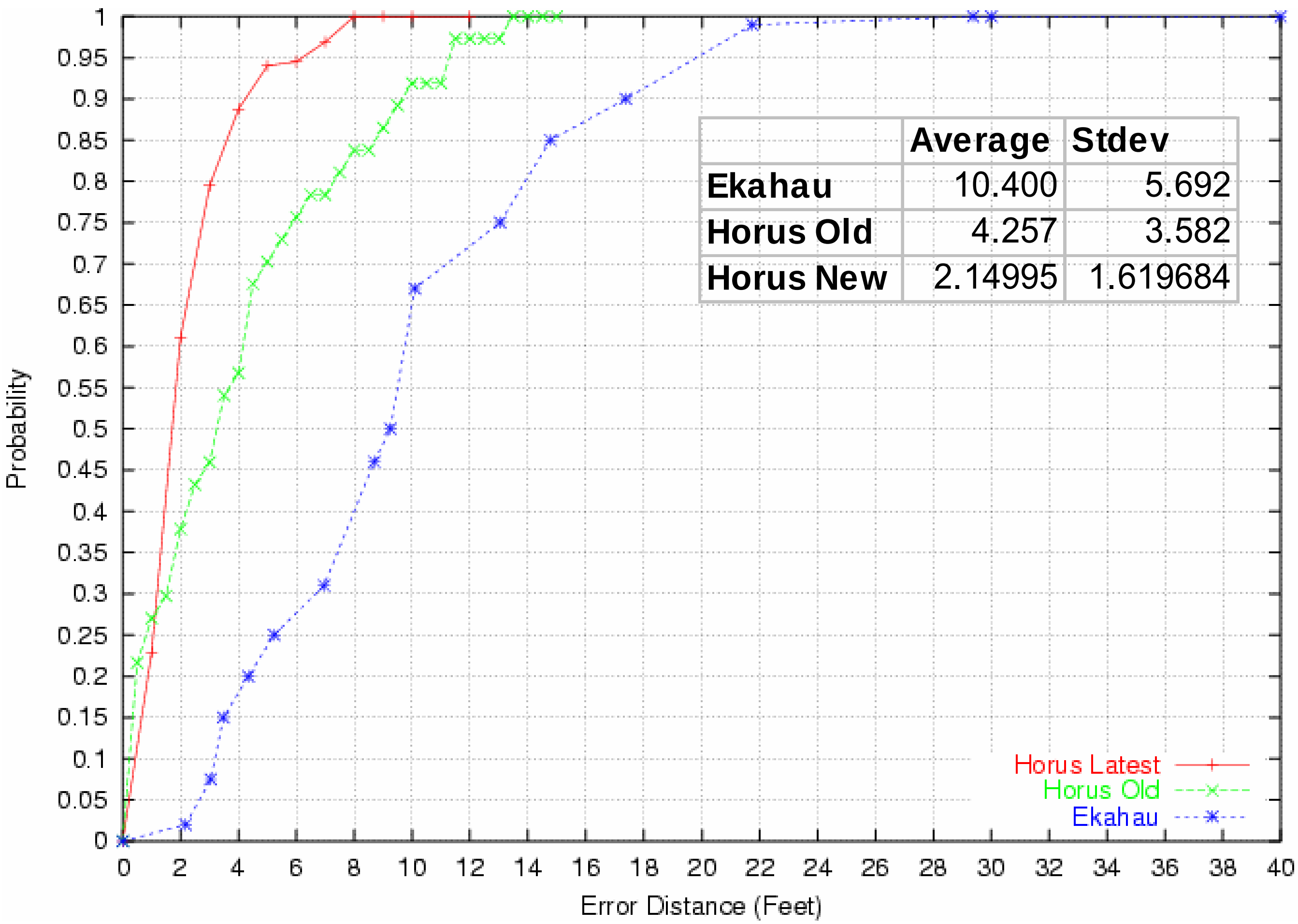
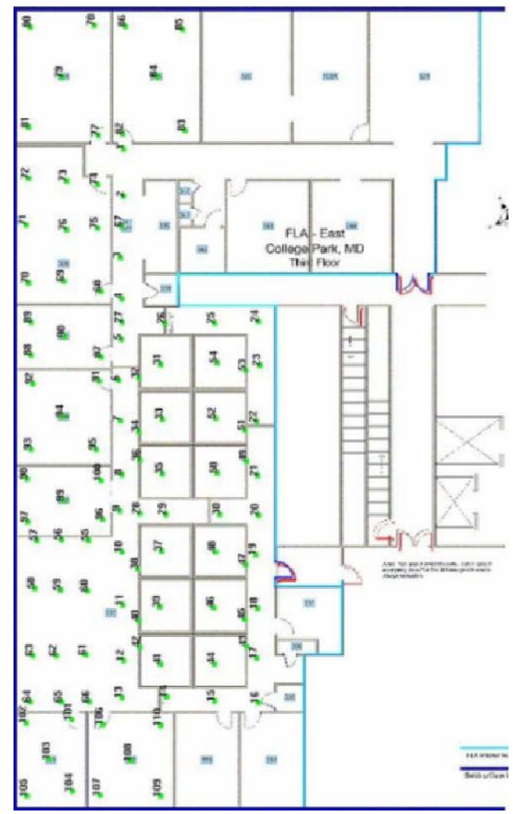
Comparison With Other Systems: Ekahau



	Average	Stdev
Ekahau	10.400	5.692
Horus Old	4.257	3.582
Horus New	2.14995	1.619684



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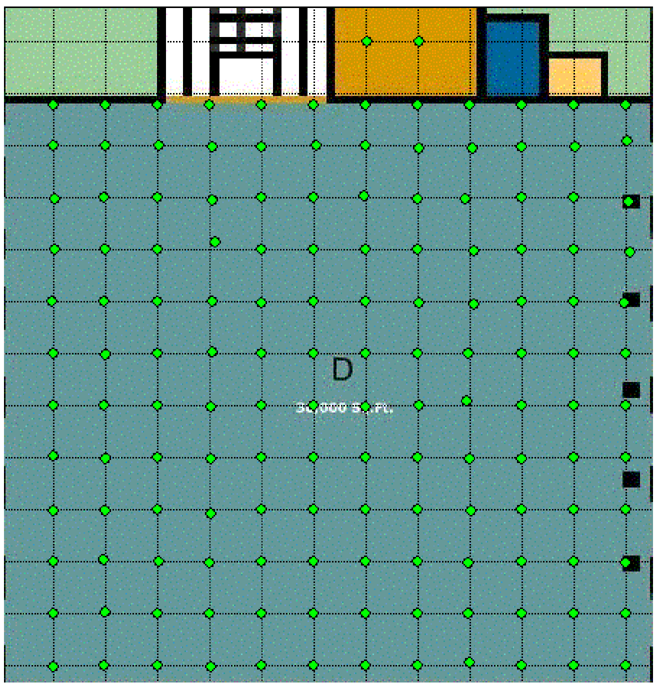
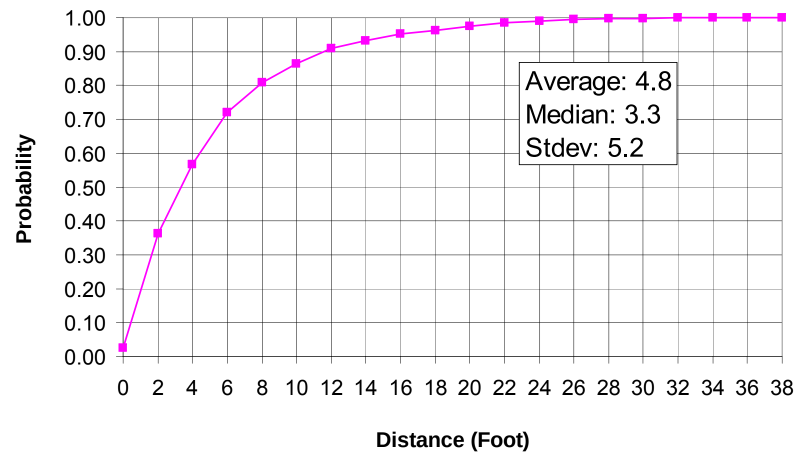
Horus

Baltimore Convention Center Test

- Large Open Hall 150’ by 150’





Passive Determination of Location
Nuzzer Technology

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Problem

- Can the location of a person be determined without the person carrying an active device, e.g. NIC or RFID ?

- The presence of a person affects the RF field and thus the RSSI.

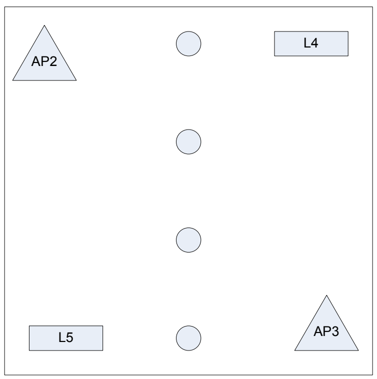
Nuzzer

Results to date

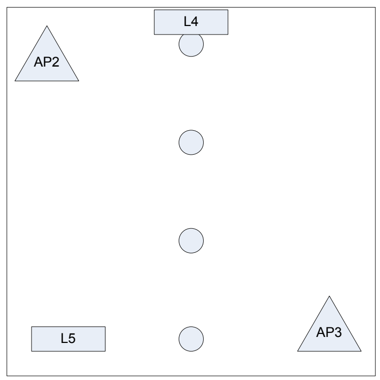
- Conducted controlled experiments in a vault – no outside RF interference
- Placed two APs and two laptops with NICs at selected locations
- Initially nobody in the room
- Then a person stands at 4 locations which are 3 feet apart.

Experimental Setup and Results

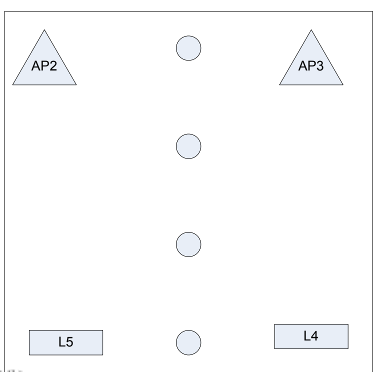
Experiment 1



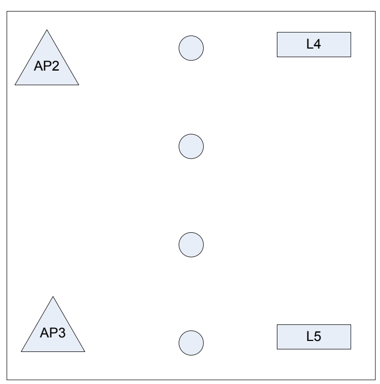
Experiment 3

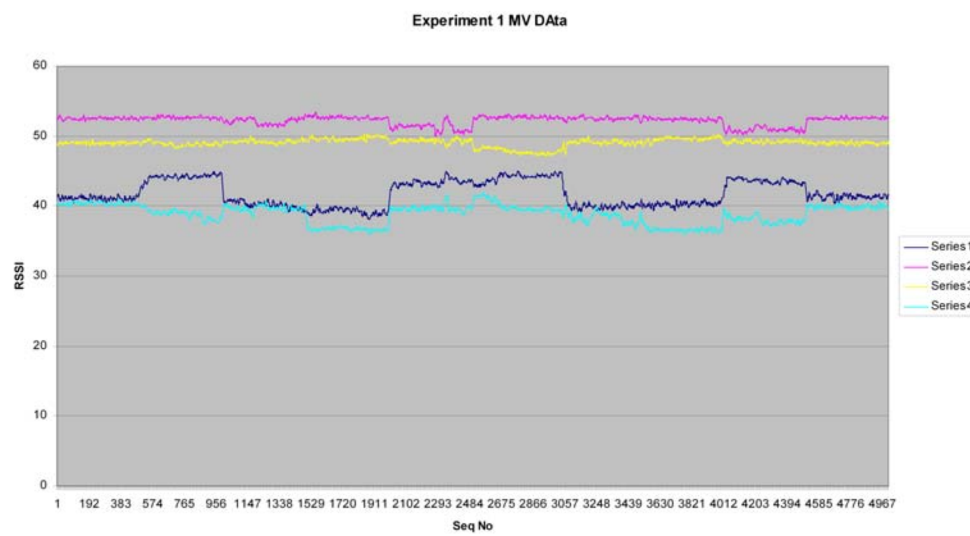


Experiment 2



Experiment 4





Training set = SET1		Training set = SET2	
total	4920	total	4920
correct	4410	correct	4243
err	510	err	677
%err	10.36585	%err	13.76016

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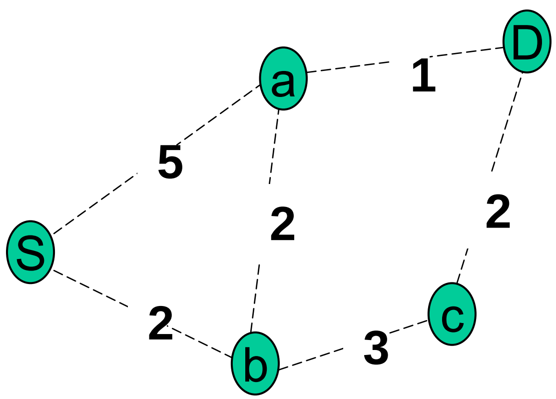
Energy Efficient Routing

EER

Energy-Efficient On-Demand Routing Protocols

- Motivation
  - Energy is a scarce resource
  - Transmissions consumes large portion of node energy
  - Noise → Error Rate → Retransmission → Energy Consumption

- To reduce energy consumption, we need reduce the number of retransmissions.
- In ad hoc networks, paths with low number of retransmissions along the hops minimize the end-to-end energy consumption.



- Develop mechanism for AODV protocol using IEEE 802.11 as MAC layer to construct energy-efficient paths.

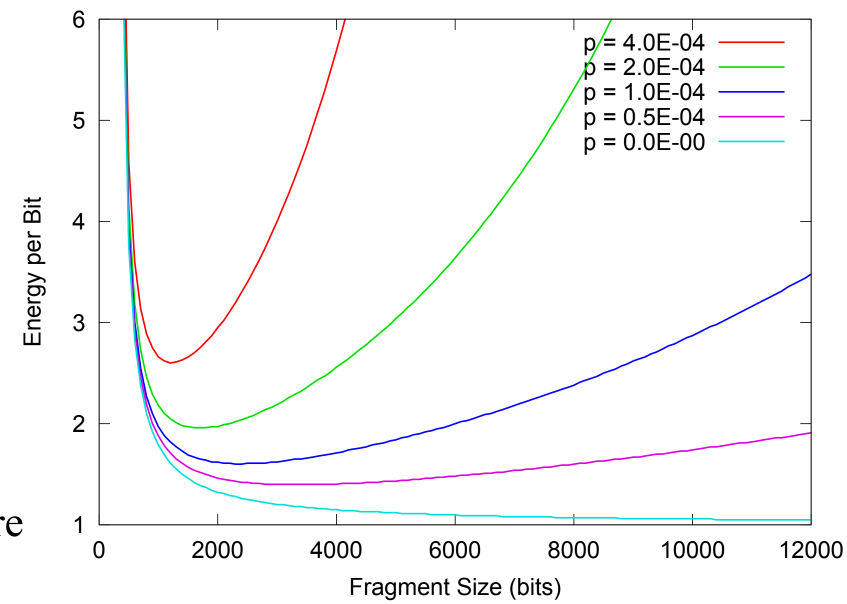
EER

Link Cost with 802.11 Fragmentation

- Cost of transmitting *L* bits using fragments of *k* bits:

$$C = v \times (o_1 + k) \times \frac{L}{k - o_2} \times \frac{1}{(1-p)^k}$$

  - ***v*:** transmission energy per bit
  - ***p*:** bit error rate over the link
  - ***o*$_1$:** bits: transmitted separately with each fragment and are not considered as a part of the fragment bits (e.g. PLCP preamble bits, PLCP header, ACK frame).
  - ***o*$_2$:** transmitted within each fragment (e.g., frame header, frame CRC).



Energy consumption for each transmitted bit where o_1=250bi o_2=300bits, and v=1unit

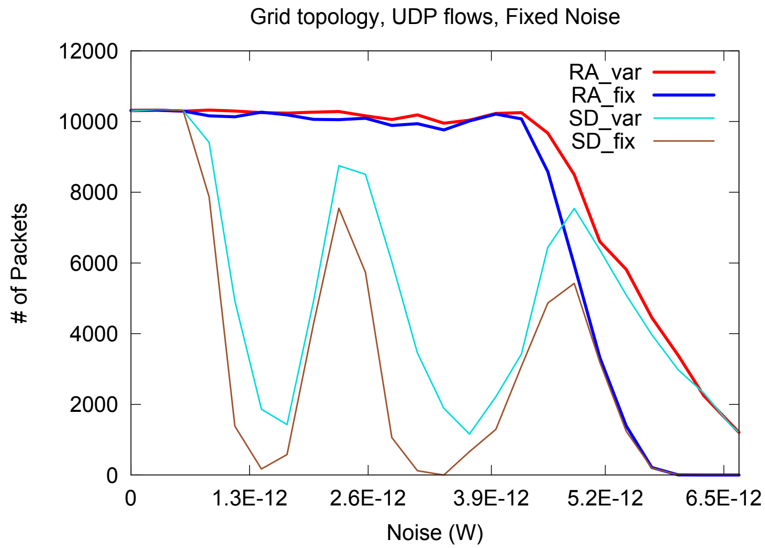
- Optimum fragment size is:

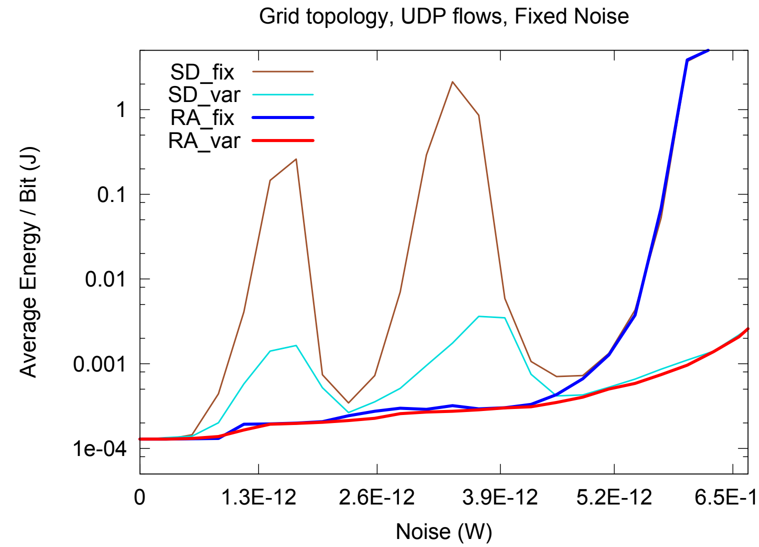
$$k^* = \frac{(o_2 - o_1)\beta - \sqrt{(o_2 - o_1)^2\beta^2 - 4\beta(o_1 + o_2 - o_1 o_2 \beta)}}{2\beta}$$

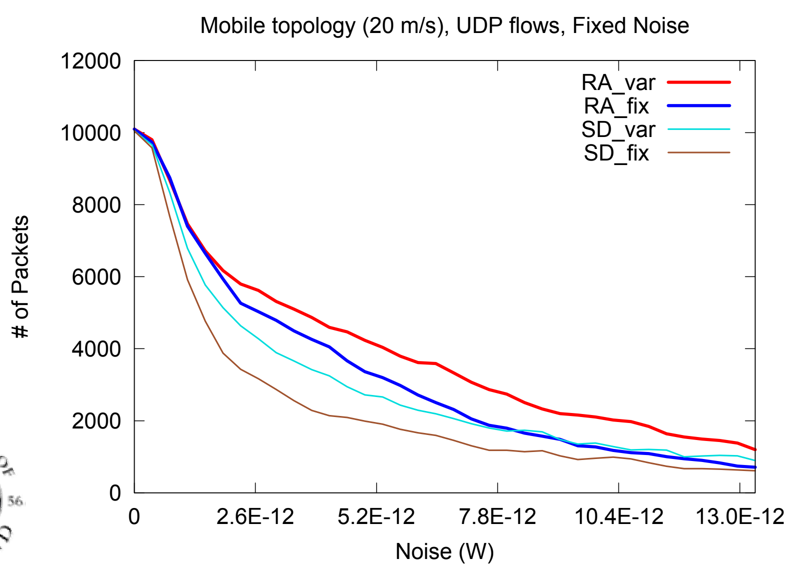
where β is $\ln(1-p)$

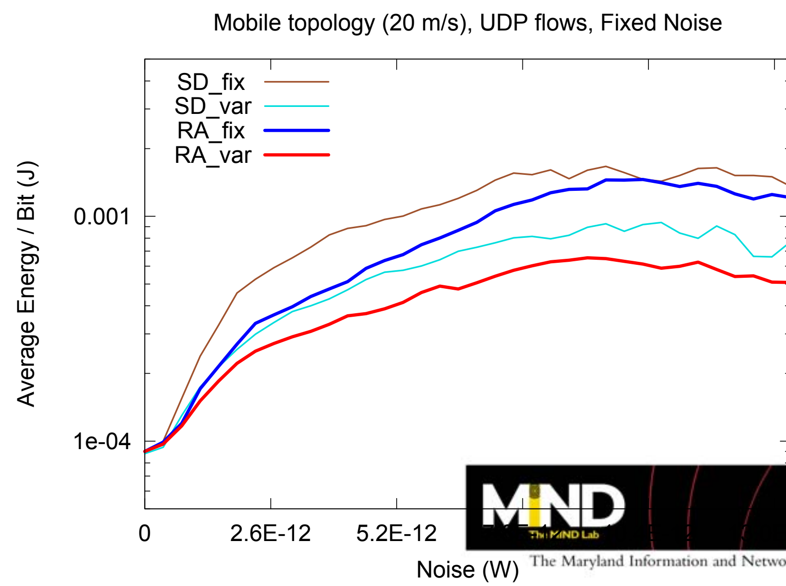
EER

Simulation Results









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Enhancing 802.11 for Noisy Environments

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Enhancement of IEEE 802.11 DCF in Noisy Environments

- In noisy environments, large number of unsuccessful transmissions are due to noise corruption (error rates).
- IEEE 802.11 doesn't differentiate between packet loss due to *packet collision* or *packet error*.

  → BEB doubles CW range in the cases of packet errors → unnecessary large idle slots → performance degradation

- Analytically study the performance of the IEEE 802.11 performance in noise environment.
- Propose an enhanced BEB mechanism to enhance the standard 802.11 BEB mechanism (BEB_{naive}) to be capable of differentiating between the collision loss and the error loss

  → BEB will double the contention window ***only*** for the case of the collision (BEB_{smart}).

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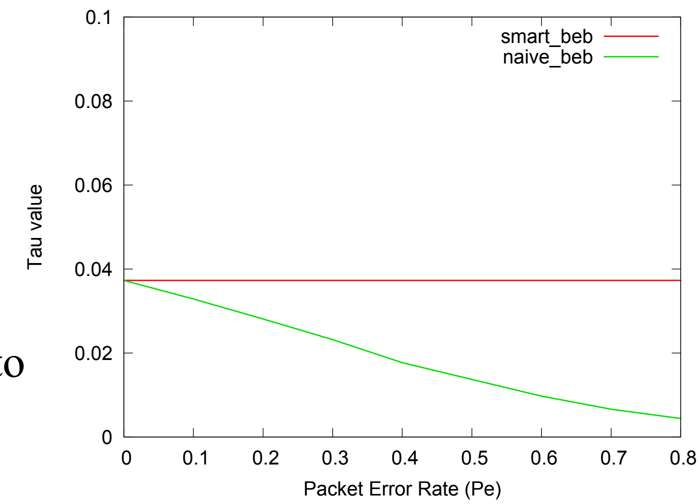
BEB_{smart} Implementation (Basic access)

- Using a Markov chain model to model BEB, we calculate the probability a node transmits in a randomly chosen time slot, τ.
- Mechanism:
  - Each node case calculate τ_{ideal}
  - Each node maintains a parameter *p*, initially set to zero.



  - When ACK is missing, nodes doubles the contention window with probability (1 – *p*) and resets its *CW* to W_0 with probability *p*.
  - Each node measures its τ every T time slots.
  - If $\tau > \tau_{ideal}$ → too *frequent* transmissions → few idle slots → *Decrease p* by δ
  - If $\tau < \tau_{ideal}$ → too *few* transmissions → large idle slots → *Increase p* by δ

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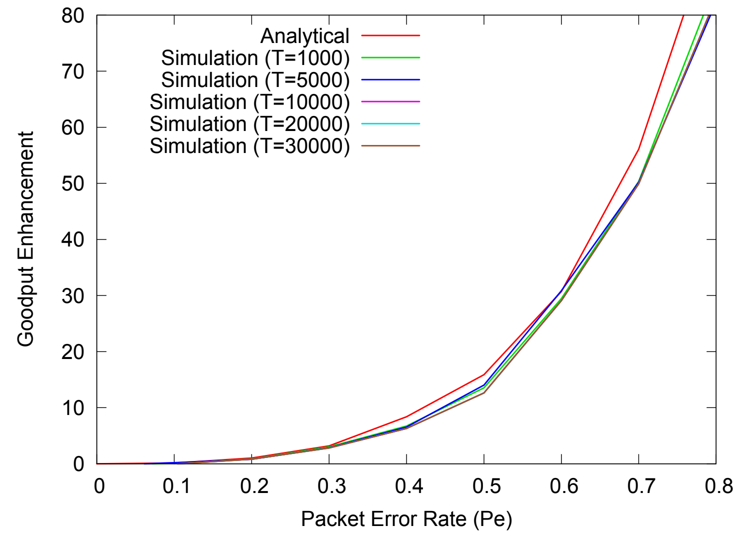
Simulation Results

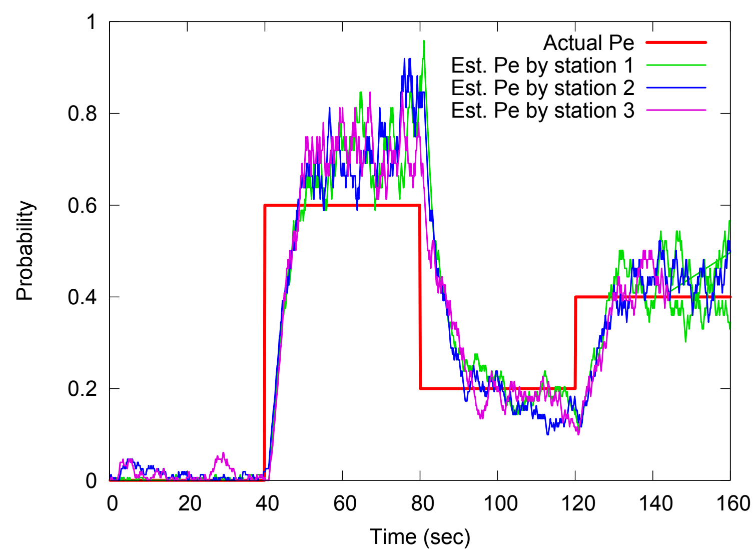
- 10 nodes transmitting data packets of size 500 bytes at data rate 22Mbps where $\delta = 0.01$.

- *p* is the percentage of the dropped packet assigned to the noise corruptions only.

$$p = \frac{(1-p_c)p_e}{p_c + p_e - p_c p_e}$$

  – From the maintained parameter *p*, a node can estimate its packet error rate p_e





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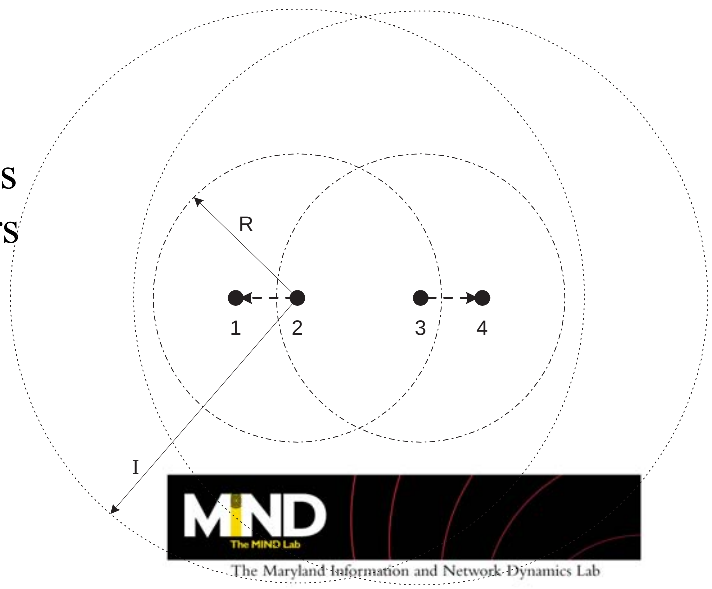
802.11 DCF Location Aware

- Problem Statement:
  - Contention based MAC protocols are based on CSMA.
  - A node transmits a packet if and only if the medium is sensed to be free.
  - A node *should not block* its transmission when the medium is *busy*, but it *has to block* its transmission only when *its transmission corrupts* the ongoing transmission(s).

- Capture phenomena:
  - Successful reception of the stronger frame in a collision
  - A frame is captured if its detected power P_r exceeds the joint interfering power P_i of I interfering powers by a minimum capture ratio α

$$P_r > \alpha \sum_{i=1, i \neq r}^{N} P_i$$



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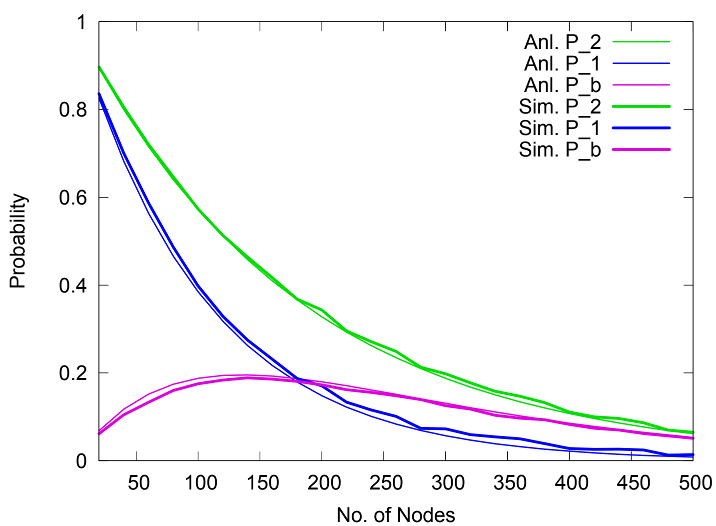
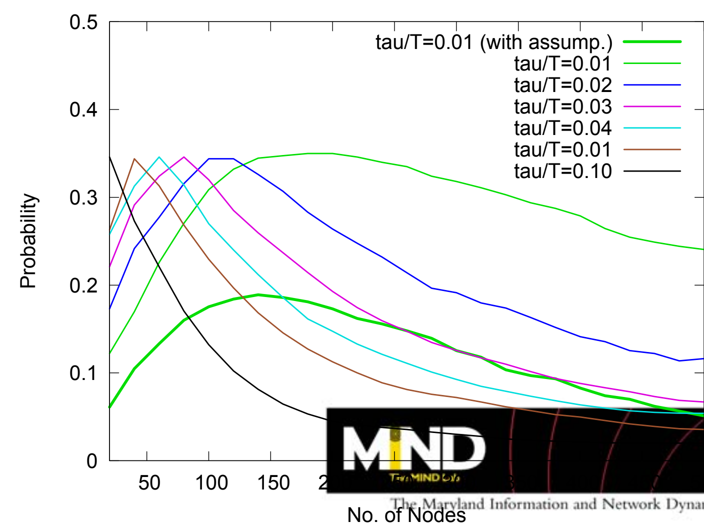
Analysis of Capture Effect

- We analytically studied the probability a node, detecting ongoing transmissions, can transmit without corrupting any of these ongoing transmissions.

$$P = [1 - \frac{\tau}{T} + \frac{\tau}{T}\int_0^I \frac{A(x)}{\pi R^2}\frac{2x}{I^2}\,dx]^{\delta\pi I^2} - [1 - \frac{\tau}{T}]^{\delta\pi I^2}$$

$$A(x) = \int_0^{min(R,\frac{x}{\sqrt{\alpha}})} 2(\pi - \arccos(\frac{x - \frac{x^2 - m^2 + (\sqrt{\alpha}m)^2}{2x}}{m}))m\,dm$$





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MacTC

802.11 MAC Traffic Characterization

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Measurement Setup

- Location: 4th floor, A.V.Williams Bldg
- Duration: Feb 9 (Monday) 0 am – Feb 22 (Sunday) 12 pm (2 weeks)
- Target traffic: Wireless LAN traffic of one umd AP (at Rm. 4149) on channel 6
- Methodology:
  - Three wireless sniffers at Rm. 4140 (closest to the AP), Rm. 4166, and Rm. 4132
  - Wireless sniffers capture MAC traffics
  - Merging three sniffers to reduce the measurement losses

MacTC

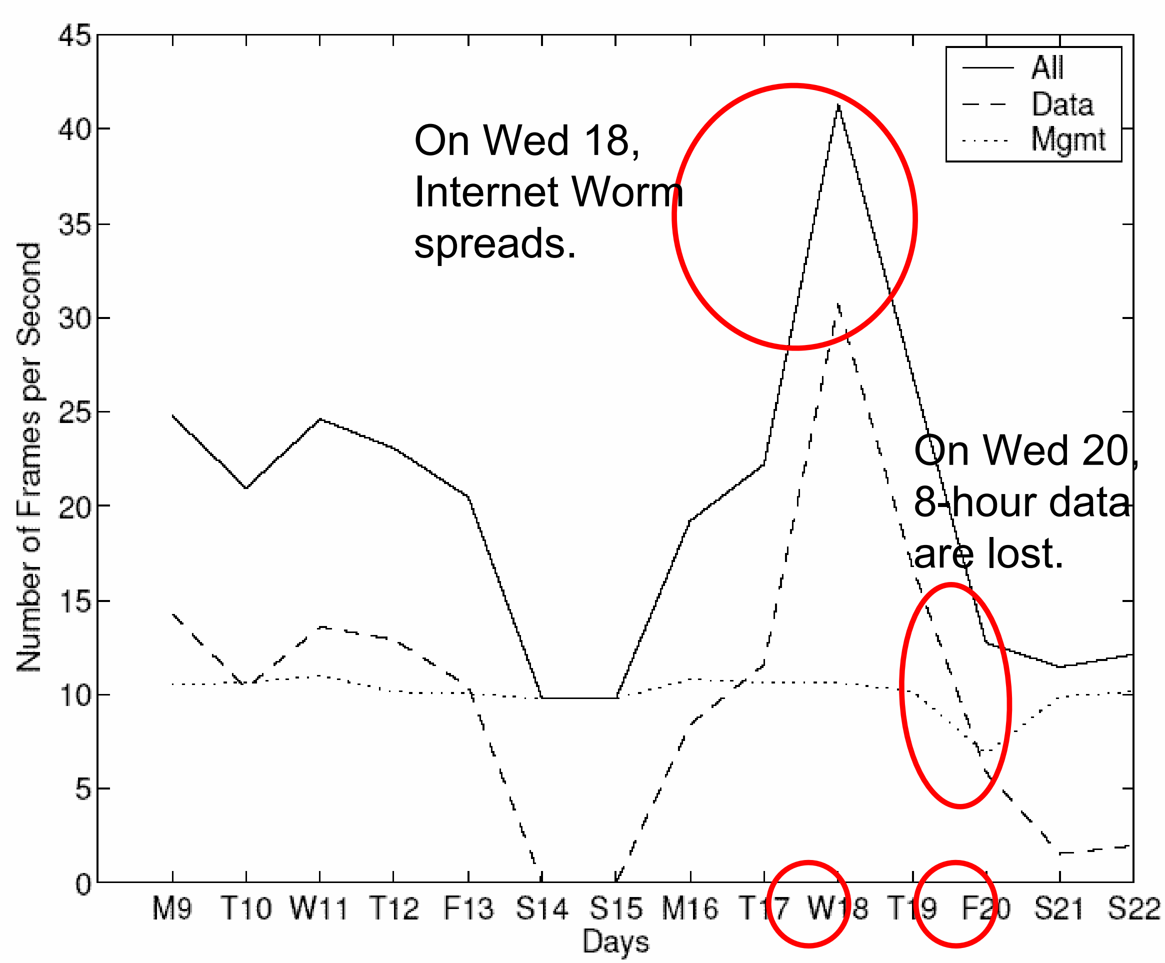
MAC Traffic Characterization

1. MAC Traffic
   - Number of frames, Bytes
2. MAC Transmission Errors
   - Retransmissions / number of frames
3. MAC Frame Types
4. MAC Frame Size Distribution
5. PHY Layer
   - Data rate and signal strength

MacTC

Two-week Pattern per MAC Type
(in number of frames per second)

- From-AP and To-AP traffics have the same shape.
- From-AP has 5 (12) times larger than To-AP in number of frames (in bytes)
- Maximum throughput within 1.5 Mbps (because channel 6 is shared with two other APs)



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Transmission Errors

- TX-Error = Number of Retransmissions / Number of Frames
- Retransmissions examined using MAC Retry field in MAC header at each frame
- More TX-errors in To-AP traffic than From-AP traffic. Why?
  - AP has better H/W than STA.
  - STAs do not adapt sending data rate (possibly an anomaly).
- Higher variability of TX-error in To-AP traffic than From-AP traffic

MAC Frame Types

- Out of Data/Management frames, Data frames (50.7%) and Beacons (46.5%) dominate
- From-AP traffic has larger avg. frame size (410 Bytes) than To-AP traffic (165 Bytes).
- (Re-)Association Request is sent at 1 Mbps but (Re-) Association Response is sent at 11 Mbps.
- Some Management frames experience severe retransmissions (up to 65%)
  - Probe Response, Re-Association Request, and Power-Save

MacTC

Anomalies of 802.11 Protocol
Severe ReTX of Management Frames

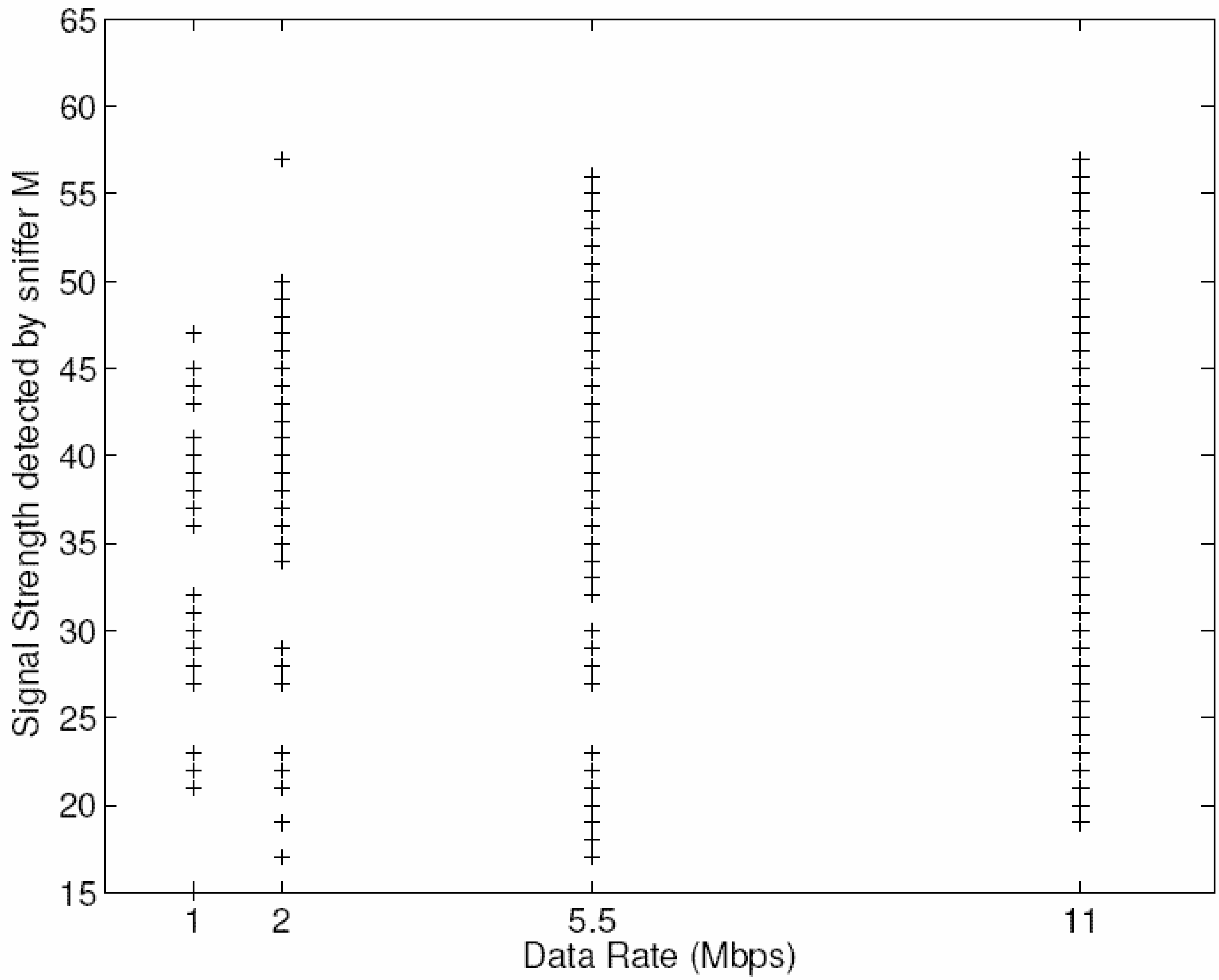
- Reasons
  - Probe Response: STA sent Probe Request and quickly switched to other APs on other channels.
  - Re-Association Request: mismatch of STA's data rate (1Mbps) and AP's (11Mbps).
  - Power-Save Poll: STA in sleep mode cannot synchronize with AP.

PHY Layer

- Examine Data rate and Signal Strength, which we can obtain in Prism2 header in each frame.
- In From-AP traffic, AP sends most frames at low data rate.
- In To-AP traffic, each STA sends most frames at high data rate.
- Observe no correlation between STA's sending data rate and signal strength received by the AP.
- (Anomaly) Client STAs do not adapt data rate according to the signal condition.

MacTC

No Correlation between STA's Data Rate and Signal Strength Received by AP



twork Dynamics Lab

TSS

Time-Step Network Simulation

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Introduction

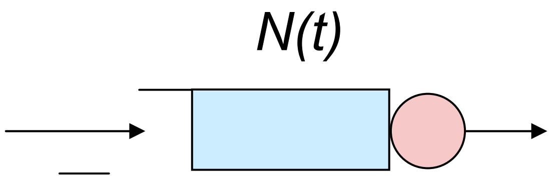
- Goal: Fast accurate performance evaluation tool for computer networks
  - Handles general control schemes (time- and state-dependent)
- Packet-level simulation:
  - Handles general control scheme precisely but prohibitively expensive
- Steady-state exact queuing models
  - Handles only simple models; no transient metrics
- Time-dependent exact queuing model
  - Only very simple systems; no state-dependent control
- Time-dependent stochastic model (fluid and diffusion approximations)
  - Handles time-dependent, but not state-dependent control

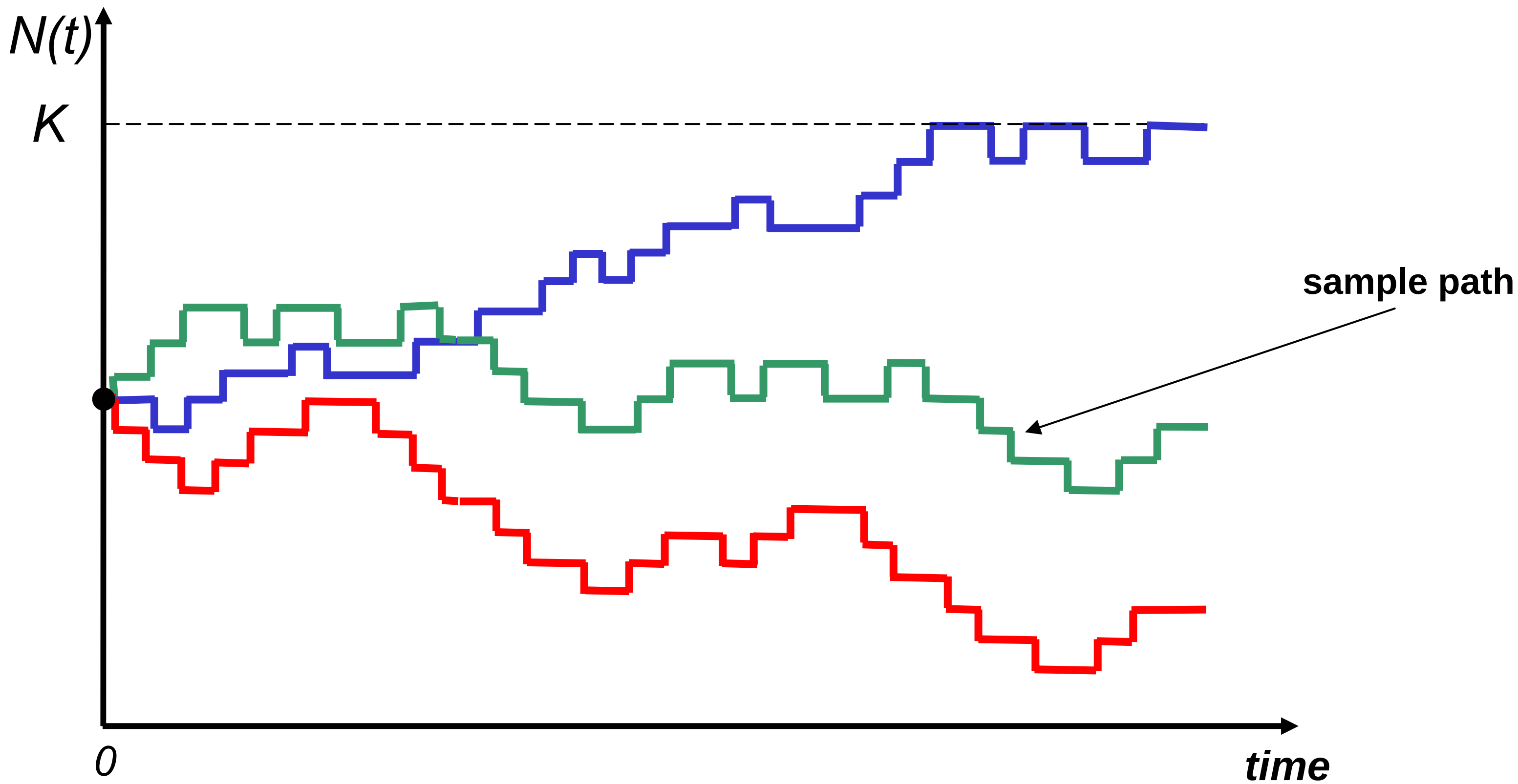
- Approach: Combine discrete-event simulation with diffusion approximation
  - Accurate, inexpensive, handles time- and state-dependent control

TSS

Hybrid time-step simulation

- Consider a single communication link
- Want to generate sample paths efficiently





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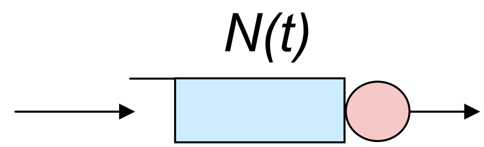
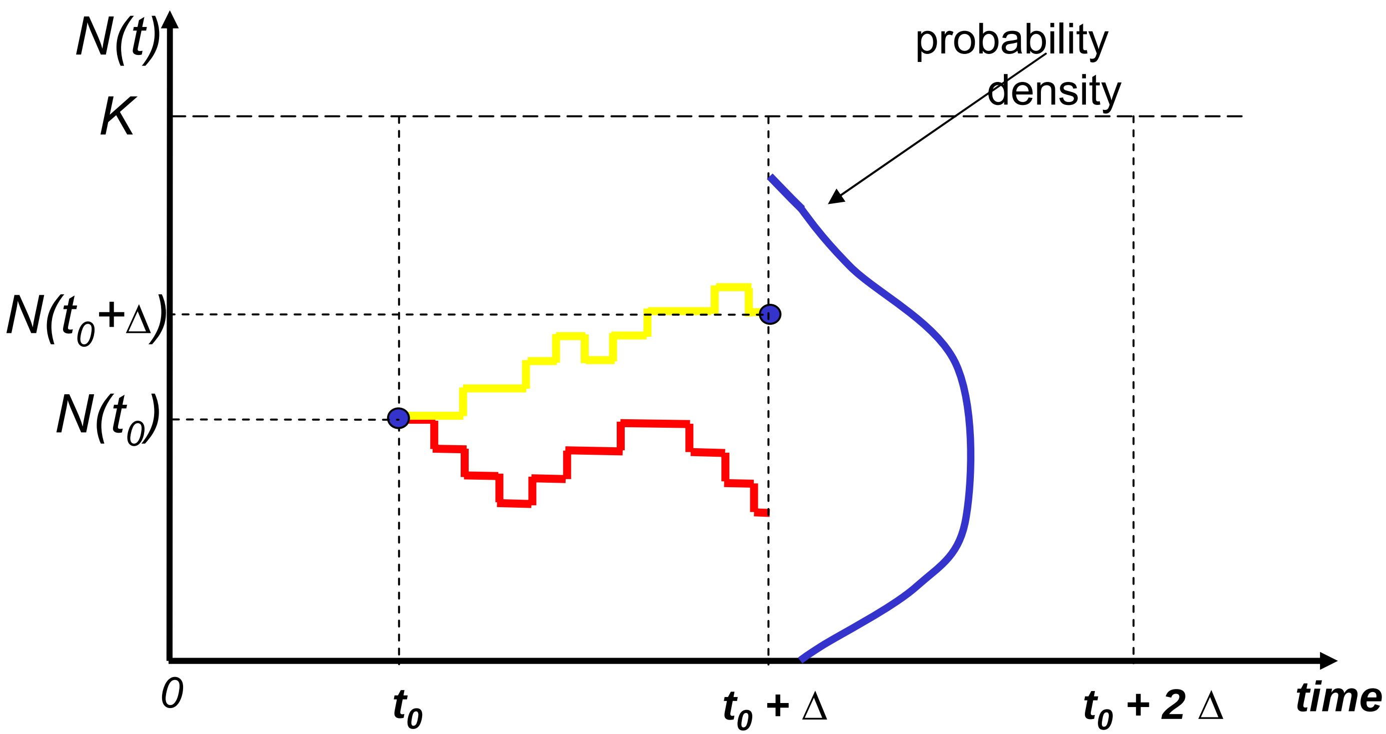
Hybrid time-step simulation

- Divide time axis into small intervals Δ
- For interval $[t_0, t_0 + \Delta]$ choose $N(t_0 + \Delta)$ randomly based on $N(t_0)$ and arrival and service processes
- Repeat for successive time intervals





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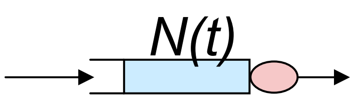
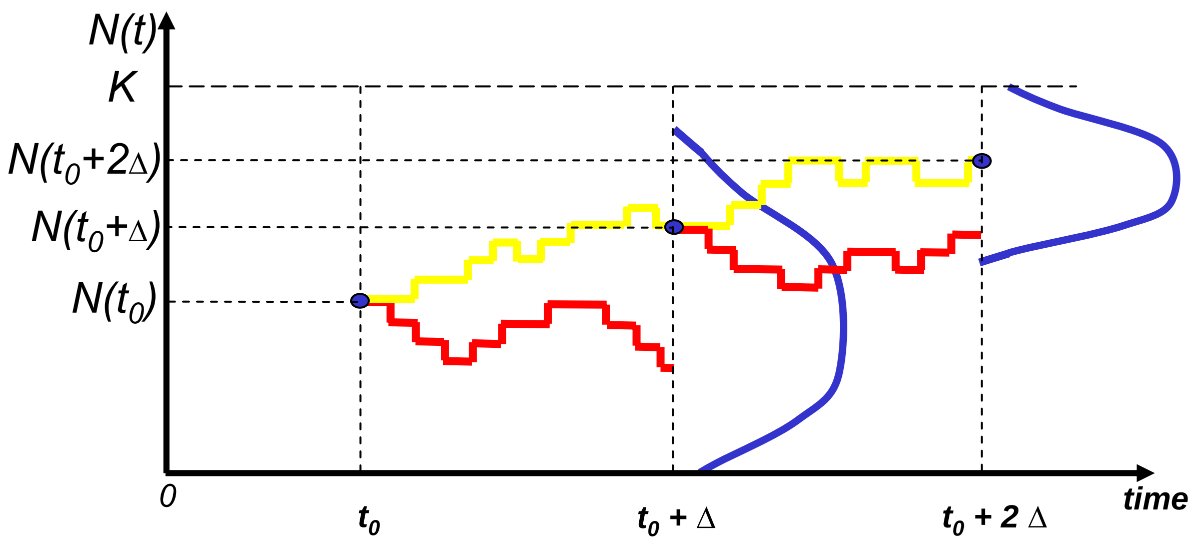
Hybrid time-step simulation

- Time/state dependent sources undergo state changes at every Δ ($\Delta \approx$ time scale of upper-layer control, e.g., RTT for TCP)
- Discrete events are not packet transmissions but time steps
- Captures state-dependent control because sample-path is explicit
- Diffusion approximation [Kolomogorov] to obtain Prob[$N(t+\Delta)$ | $N(t)$]
  - Arrival and service processes defined by time-varying mean and variance





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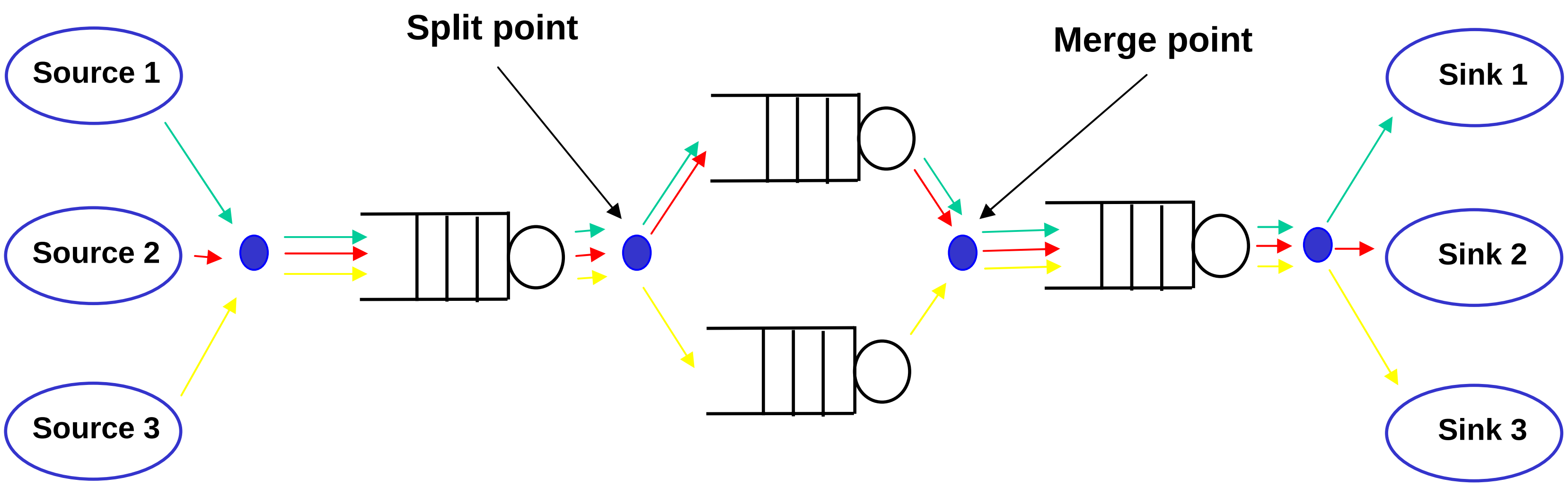
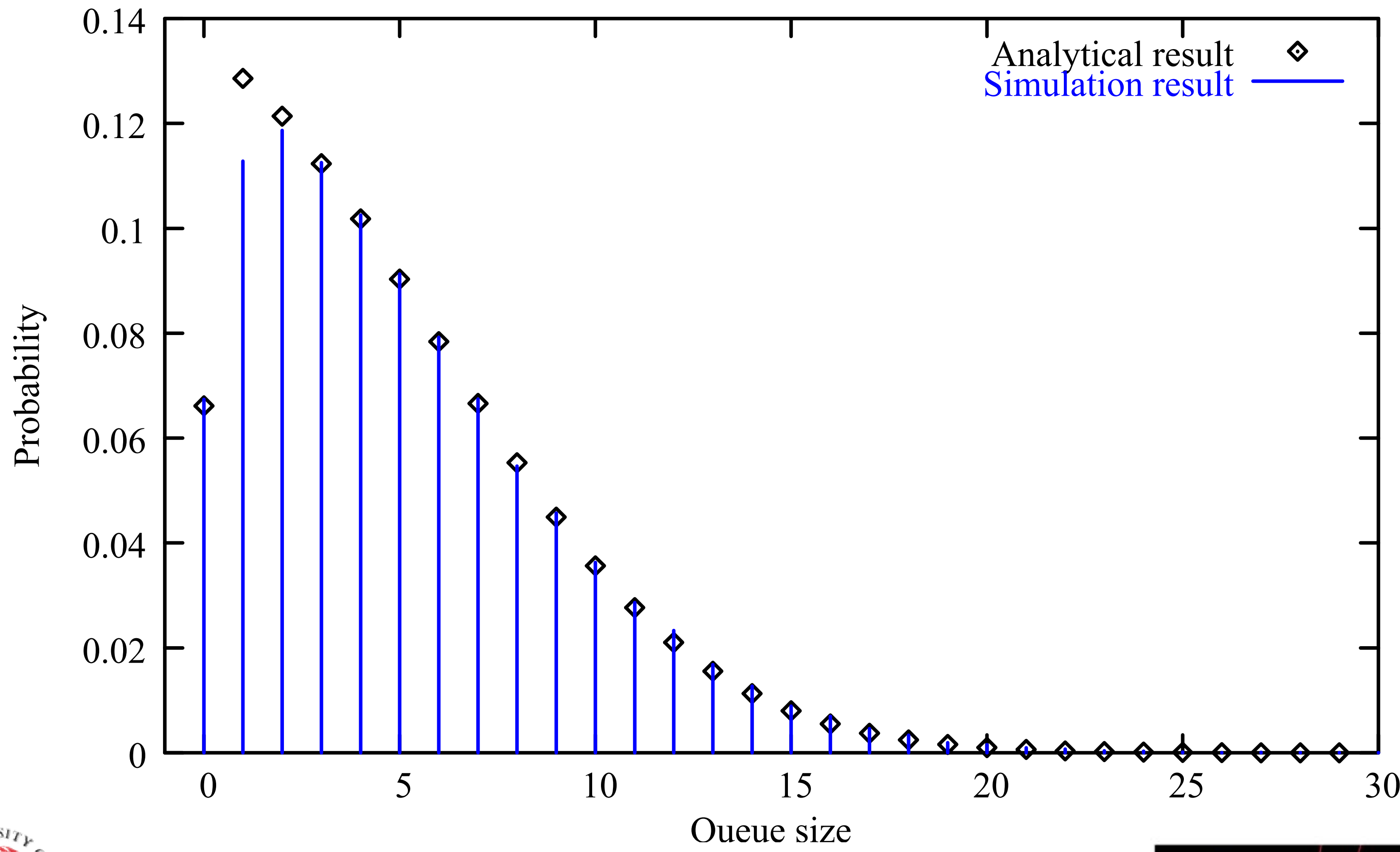
Extension to network of queues

- For each interval [$t, t + \Delta$]
  - Approximate queue departure and internal flows by renewal processes characterized by the first two moments
  - Routing probabilities determined by queue occupancy
- Formulate equations for merging and splitting flows

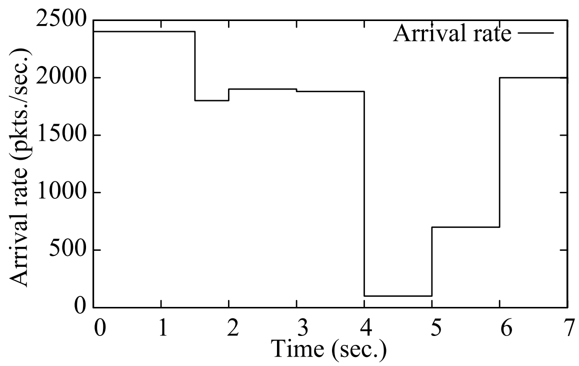


Example: Queue size prob density

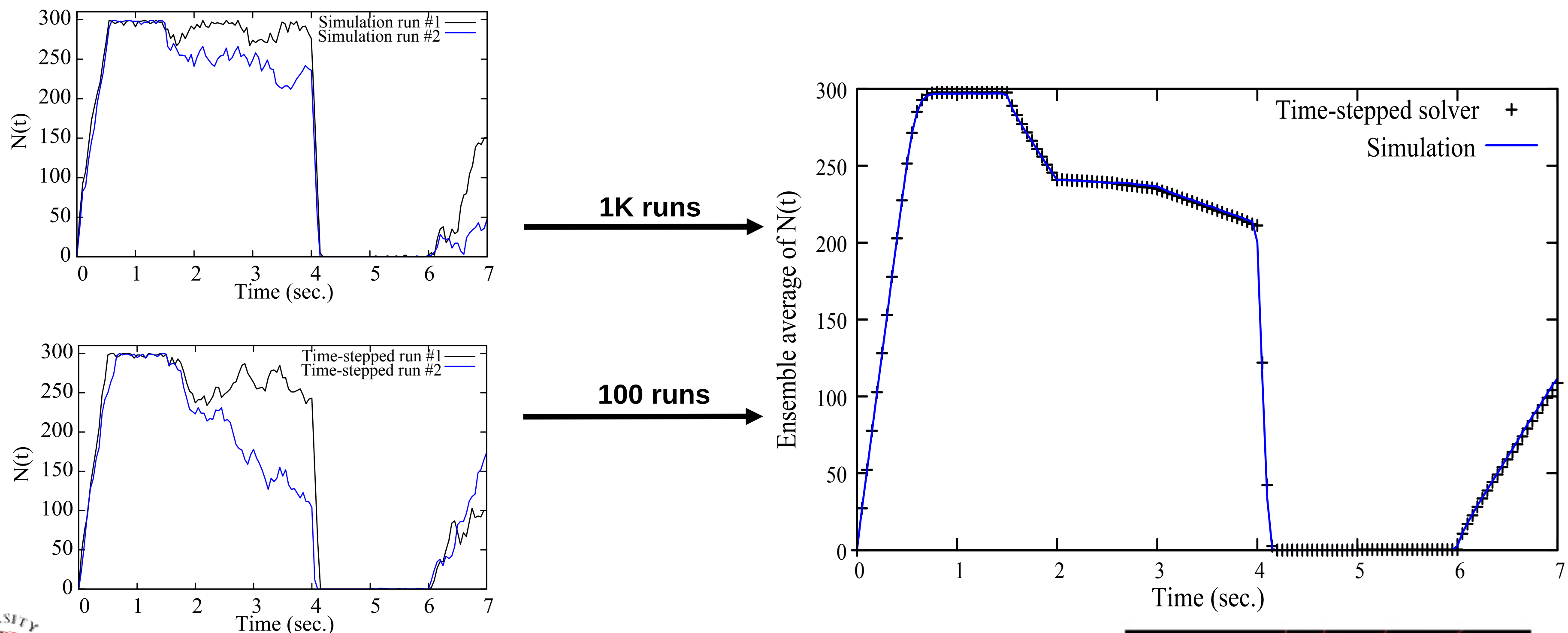
- GI/D/1/40 queue, $\lambda=800$, $c_A=1$, and $\mu=810$, $N(t) = 2$, $\Delta=0.05$



TSS — Example: TSS vs. packet-level simulation



- GI(t)/D/1/300 queue, uniform arrival dist, μ=1900
- Computation time of one run:
  - 10 Mbps link - simulation 1.5 sec., hybrid 0.1 sec.
  - 100 Mbps link - simulation 15 sec., hybrid 0.1 sec.
- Time-step simulator converges faster due to smaller probability space



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Time-step simulation - Conclusions

- Time-stepped simulation using diffusion approximation
- Fast and accurate alternative to packet-level (discrete-event) simulation
- Computational complexity not affected by increasing link bandwidth
- Handles state-dependent control schemes
- Yields time-dependent evolution of performance metrics

- Future research plans
  - Extend queue model to handle wireless links (802.11)
  - Extend to other router disciplines (RED, AQM, CBQ)
  - Optimize numerical computation
  - Detailed comparisons with simulation for large networks