An Intelligent Rate Controller for Video Traffic in VANET

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Outlines

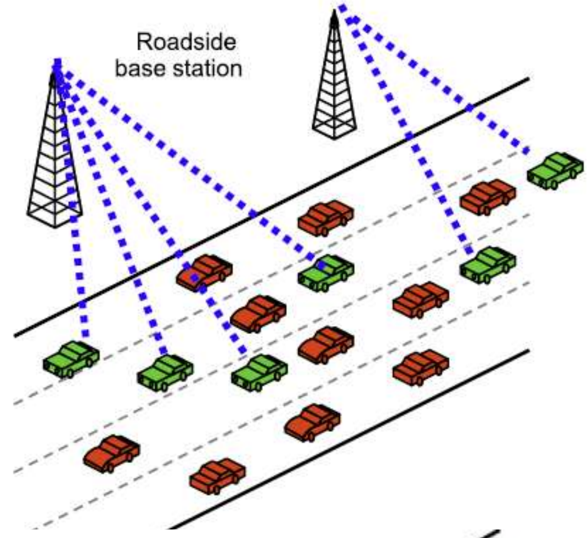
- Introduction
  - Background
  - Objective and Motivation
- Our New Scheme: IntelRate
- Performance Evaluation
- Conclusion

Background (1)

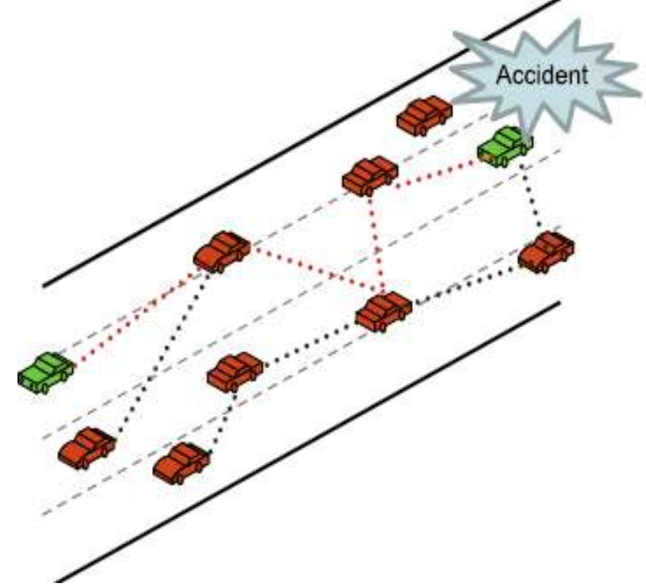
- Importance of multimedia communication in wireless network
  - Applications over ad hoc network includes rescue operations, disaster recovery, connect people where an infrastructure is unavailable
  - Multimedia over cell phone or portable tablets
    - Provide video surveillance to monitor home and business in real time;
    - Make video conferencing not just sitting on the meeting rooms
    - Entertain people with video gaming and streaming anywhere anytime.
  - Video traffic in VANET (Vehicular Ad hoc NETworks)
    - Provide multimedia communication, road safety, emergency response, traffic control/management, etc..

Background (2)

- VANET consists of:
  - A cluster of cars involved in vehicle to vehicle and/or vehicle to infrastructure communication.



  - Basically automobiles, Road Side Units (RSU) and the backhaul network.



Background (3)

- **Challenges:**
  - Good QoS requirements for real-time video applications and multimedia streaming
  - Need to combat data traffic congestion
  - Channel fading and asymmetrical distribution of resources
  - Requirement of mobility and scalability to support video communication
  - Very difficult to achieve high link utilization and fair bandwidth allocation while maintaining small queue length and minimizing packet loss.

Objective and Motivation (1)

- **Objectives**
  - Tackle VANET traffic congestion control
  - Improve on previous work
  - Design a scalable algorithm for the transportation of video over VANET
  - Conducting analysis of video transportation

Objective and Motivation (2)

- TCP, TFRC and traditional AQM (e.g., RED) congestion control algorithms tend

  -to cause severe oscillations and even instability

  -not to perform well in wireless networks.

- The reasons are

  -their controls are window-based

  -implicit protocols in nature.

  -can not provide the precise congestion information to the sources.

Objectives and Motivation (3)

- The explicit congestion control protocols (such as XCP, RCP and API-RCP) are able to
  - provide explicit and precise congestion signals to help sources regulate the sending rate.
  - prevent the network from severe degradation in big bandwidth-delay network.
- However, they have the following drawbacks.
  - potential mis-estimation of bottleneck bandwidth (such as in XCP and RCP) can cause significant performance problems, e.g., throughput fluctuations, utilization reduction, etc.
  - estimation of network parameters consumes CPU and memory resources in a router or a mobile node.

Outlines

- Introduction
- The IntelRate Controller
  - Introcution to IntelRate
  - Methodology
  - IntelRate Design
- Performance Evaluation
- Conclusion

Introduction to IntelRate (1)

The IntelRate controller [LiYa10]

- is fuzzy logic control-based
- can avoid the estimation of network parameters (e.g., bottleneck bandwidth, the number of flows)
- but maintains the advantages of the existing explicit congestion control protocols such as XCP, RCP and API-RCP.
- only depends on router IQSize (Instantaneous Queue Size)

  a parameter which can be accurately measured to gauge the traffic level in a router.

Introduction to IntelRate (2)

- The advantages not to estimate the network parameters
  - ➢ automatically adapt itself to the new network conditions regardless of parameter change
  - ➢ avoid the large steady state error and instability

    -introduced by the potential mis-estimations of network parameters
  - ➢ work better in dynamic network environment
  - ➢ save CPU and memory resources

    -due to the parameter estimation tasks

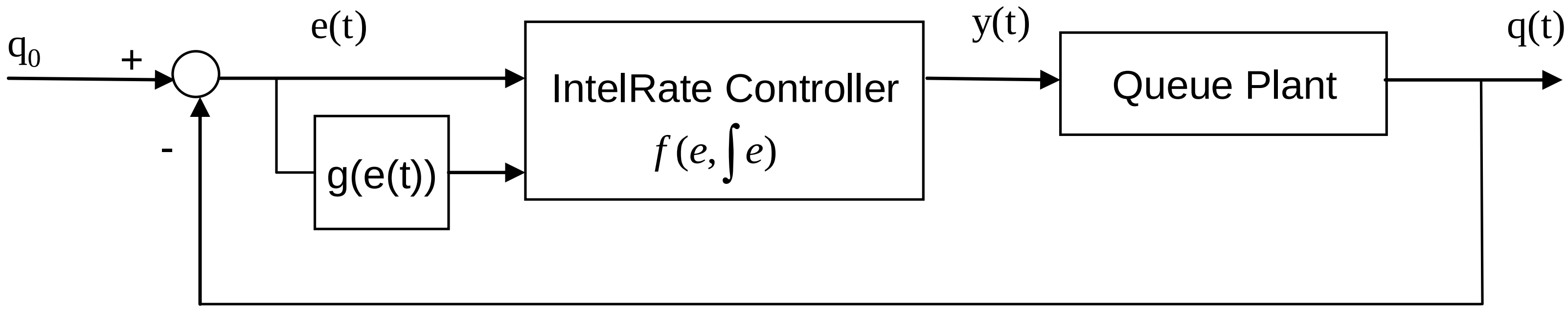
[LiYa10] Jungang.Liu and Oliver Yang, "Design and evaluation of an intelligent rate controller for heterogeneous networks," *IEEE Globcom 2010*, Miami, U.S.A, Dec.6-10, 2010.

Methodology

- Incorporates
  - heuristic features of FLC (Fuzzy Logic Control)
  - queue size well reflects the onset of congestion
  - RSVP (Resource Reservation Protocol)
    - by assuming every source has a desired sending rate.

- Use Opnet simulation to
  - evaluate the performance of the controller
  - verify the controller’s effectiveness.

IntelRate Design (1)



- Controller inputs
  - $e(t)=q_0-q(t)$ $\qquad g(e(t)) = \int e(t)dt$
  - q_0 is the TBO (Target Buffer Occupancy)
  - $q(t)$ is the IQSize

- Controller output
  - $y(t) = \sum_{i=1}^{M} u_i(t-\tau_i)$

IntelRate Design (2)

- Fuzzy Logic Rule base
  - linguistic values of *e(t)* and *g(e(t))* designate input values in an increasing order from "NV" to "PV".
  - linguistic values of *u(t)* designate the output values in an increasing order from "ZR" to "MX".
- Each rule is in a "If…Then…" format, e.g. (ZR, PS, BG)

Table 1: Rule Table for the IntelRate Controller

Allowed Throughput *u(t)*		*e(t)*								
		NV	NL	NM	NS	ZR	PS	PM	PL	PV
g(e(t))	NV	ZR	ZR	ZR	ZR	ZR	ES	VS	SM	MD
	NL	ZR	ZR	ZR	ZR	ES	VS	SM	MD	BG
	NM	ZR	ZR	ZR	ES	VS	SM	MD	BG	VB
	NS	ZR	ZR	ES	VS	SM	MD	BG	VB	EB
	ZR	ZR	ES	VS	SM	MD	BG	VB	EB	MX
	PS	ES	VS	SM	MD	BG	VB	EB	MX	MX
	PM	VS	SM	MD	BG	VB	EB	MX	MX	MX
	PL	SM	MD	BG	VB	EB	MX	MX	MX	MX
	PV	MD	BG	VB	EB	MX	MX	MX	MX	MX

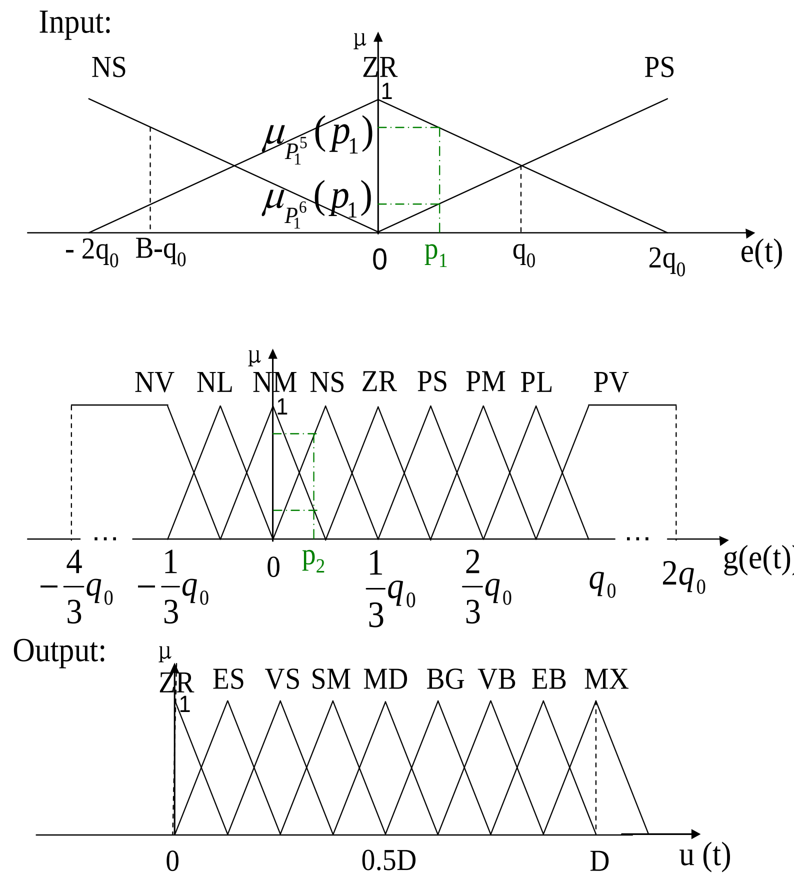
IntelRate Design (3)

Membership function

-the horizontal axis of *e(t)* and g(e(t)) is a function of q_0.

-the horizontal axis of *u(t)* is a function of D

- the biggest desired rate among all the flows passing the router.



IntelRate Design (4)

Analsysis:

Why is the IntelRate Controller Superior to Other Controllers?

The IntelRate controller

-the design uses the <u>nonlinear</u> control principle

- its gain parameters can vary over time

$$u(t) = \boldsymbol{K_{fP}(t)} e(t) + \boldsymbol{K_{fI}(t)} g(e(t)) + K_c$$

The existing explicit congestion controllers

-such as XCP, RCP or API-RCP

-their designs use the classical <u>linear</u> PI principle

- their gains are fixed.

$$u(t) = \boldsymbol{K_P} e(t) + \boldsymbol{K_I} g(e(t))$$

This is why the IntelRate controller without evaluating network parameters can adapt itself to the new network conditions upon the parameter changes.

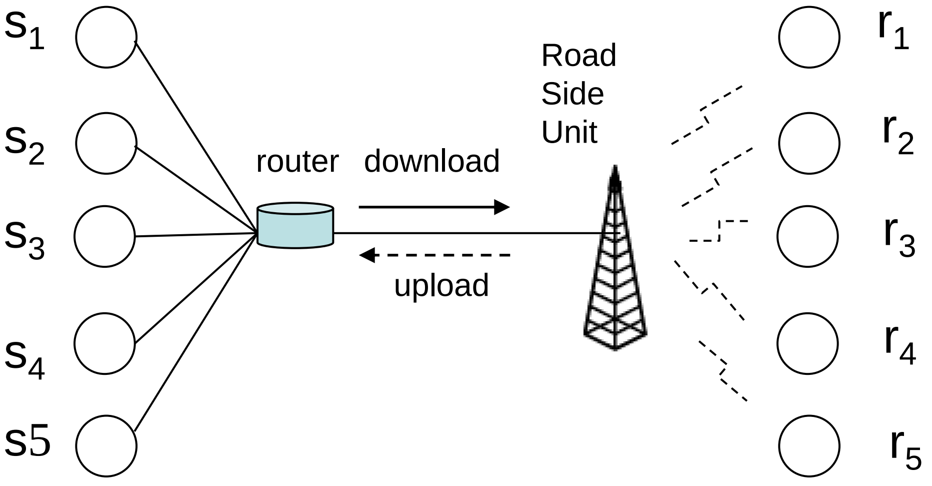
Outlines

- Introduction
- Our New Scheme: IntelRate
- Performance Evaluation
  - Simultation Setup
  - Robustness to Sudden Traffic Change
  - Comparison with XCP
- Conclusion

Simulation setup (1)

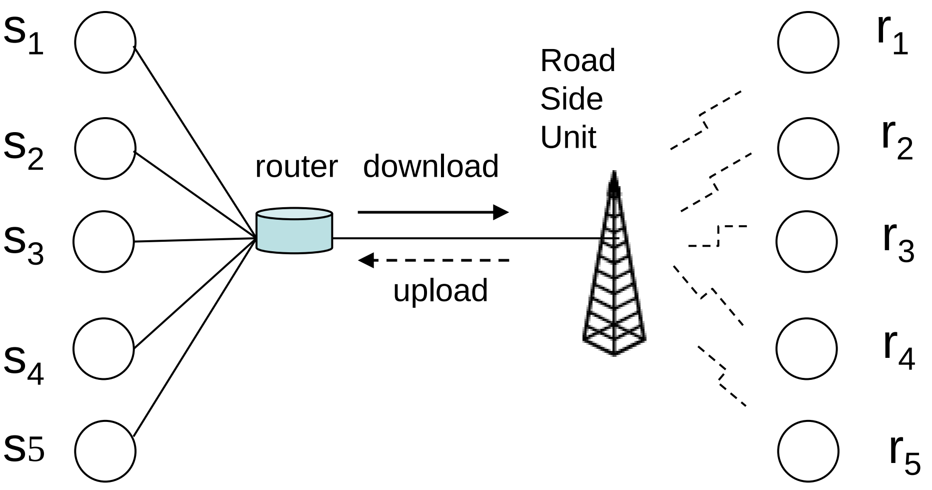
Simulation Settings

- OPNET modeler is used to evaluate the performance of the IntelRate controller.
- Simulation topology (multimedia streaming scenario)
  - 5 source–destination pairs (r_i are the vehicles and s_i are the multimedia sources.)
  - IEEE 802.11 WiFi with 11Mbps wireless bandwidth
  - The backhaul network has 1Gbps bandwidth and propagation delay of 100ms
  - The wireless side of the Road Side Unit is a bottleneck
  - TBO (Target Buffer Occupancy) in bottleneck is set to 60 packets for the IntelRate controller

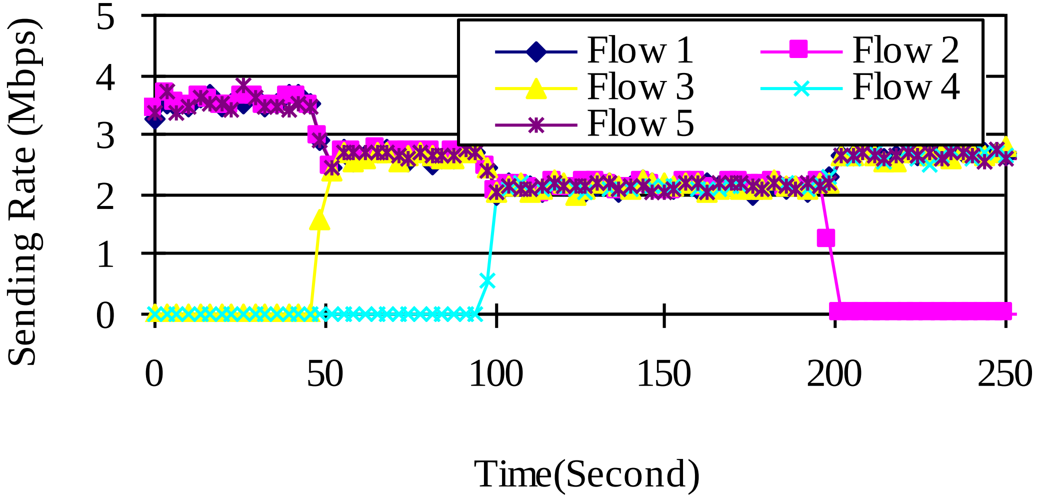


Robustness to Sudden Traffic Change (1)

- In the first 50 seconds,
  - only video flows 1, 2 and 5 in operation.
- At t=50s,
  - Flow 3 joins in the traffic
- At t=100s.
  - Flow 4 joins in the traffic
- At t=200s.
  - Flow 2 withdraws traffic



Robustness to Sudden Traffic Change (2)



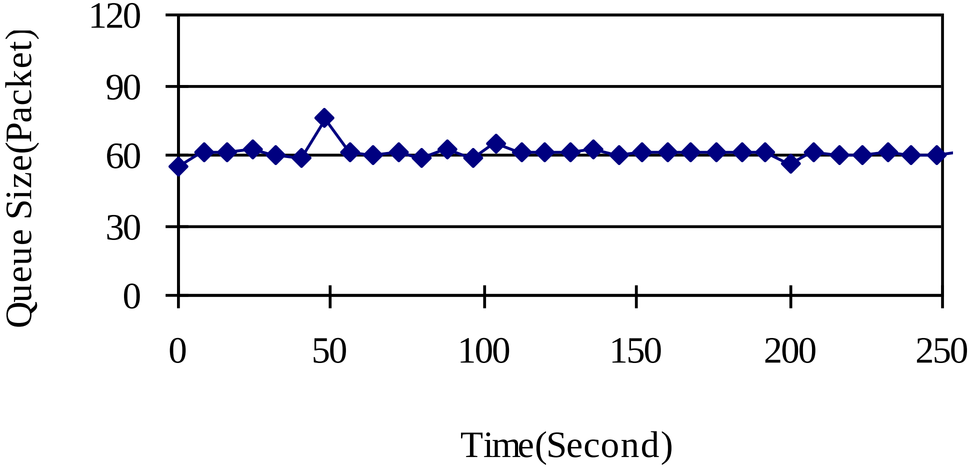
Parameter settings:

- Packet size is 360 bytes.
- In the first 50 seconds,
  - only video flows 1, 2 and 5 in operation.
- At t=50s,
  - Flow 3 joins in the traffic
- At t=100s.
  - Flow 4 joins in the traffic
- At t=200s.
  - Flow 2 withdraws traffic

- In the first 50s, Flow 1,2 and 5 share the 11Mbps bandwidth, the sending rate of each is about 3.3Mbps.
- At t=50s, after Flow 3 joins in, the sending rate of Flow 1,2 and 5 decreases and now 4 flows share the 11Mbps bandwidth, the sending rate of each is about 2.75Mbps.
- At t=100s, after Flow 4 joins in, the sending rate of Flow 1,2,3 and 5 decreases and now 5 flows share the 11Mbps bandwidth, the sending rate of each is about 2.2Mbps.
- At t=200s, after Flow 2 withdraws, the sending rate of Flow 1, 3,4 and 5 increases and 4 flows share the 11Mbps bandwidth again, the sending rate of each is about 2.75Mbps.

Robustness to Sudden Traffic Change (3)

IQSize (Instantaneous Queue Size) performance :



Parameter settings:

- Packet size is 360 bytes.
- In the first 50 seconds,
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- At t=50s,
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- At t=100s.
  - Flow 4 joins in the traffic
- At t=200s.
  - Flow 2 withdraws traffic

- The IQSize is well controlled and operating at the TBO of 60 packets
- The traffic dynamics at t=50s,100s or 200s are reflected by the IQSize
- The fluctuation of the IQSize at t=50s,100s or 200s is small and can settle back to TBO of 60 packets very quickly
- Demonstrate good stability.

Comparison with XCP (1)

Recall that XCP needs to estimate the bandwidth, and the IntelRate controller need not do so.

Simulation parameter settings:

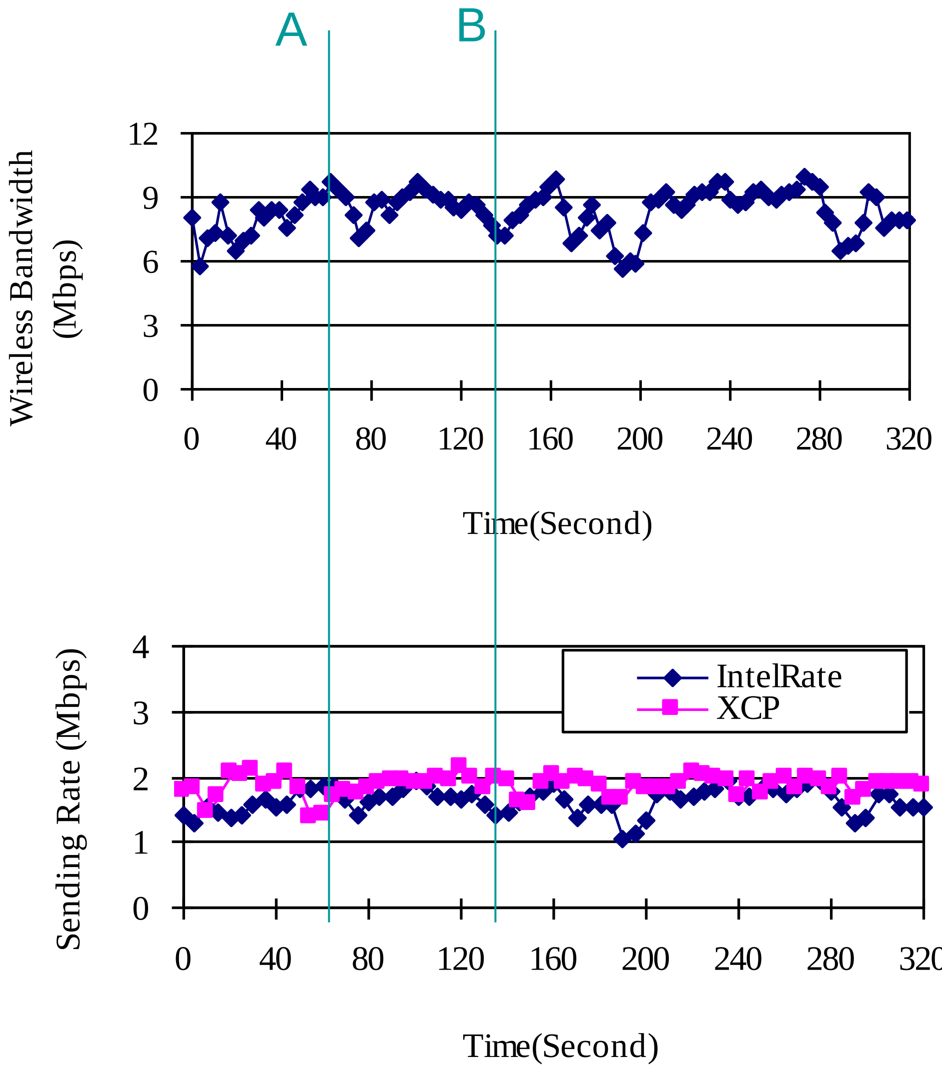
- The same settings as the last experiment.
- The bottleneck bandwidth dynamics has a Rayleigh distribution
- The XCP design parameters are the same as the values adopted in the XCP paper (*SIGCOMM 2002*), i.e., α=0.4 and β=0.226.

Comparison with XCP (2)

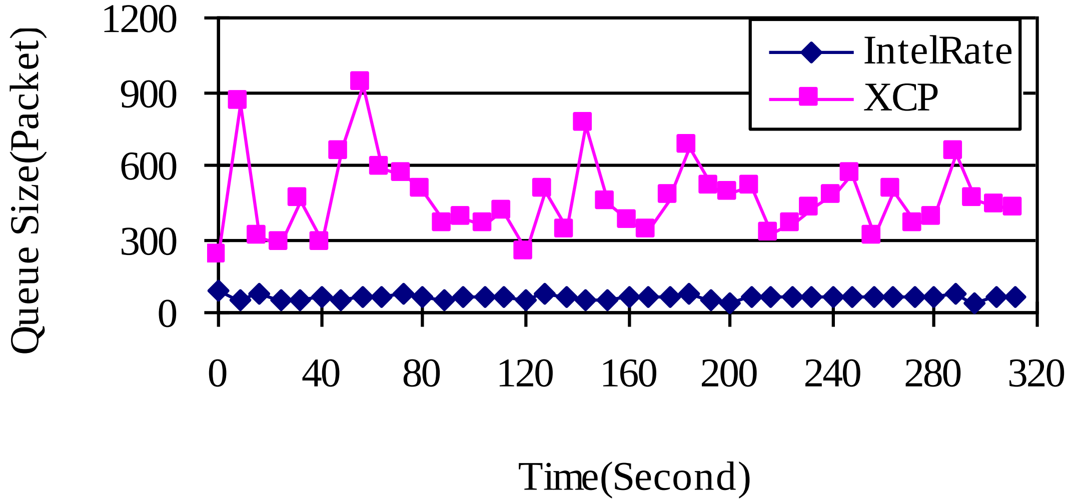
- Observation on Sending Rate

  - IntelRate flows well follow the fluctuations of wireless link bandwidth. The time points at A and B show two typical examples.

  - XCP flows does not follow the bandwidth fluctuations.



Comparison with XCP (3)



- Observation on IQSize

  - The IntelRate IQSize stably operates around the TBO of 60 packets

  - The XCP IQSize oscillates around 300-900 packets.

Comparison with XCP (4)

Analysis:

- The mis-estimation of wireless bandwidth due to the efficiency equation of XCP

$$\phi = \alpha \cdot (c - y(t)) - \beta \cdot Q / d)$$

- The IntelRate is based on the heuristic expert knowledge so that

  * the source is able to find a new rule according to the queue size variation and thus

  * adapting itself to the new bandwidth condition.

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Concluding Remarks

- Designed the IntelRate controller

- We have shown that it
  - relies on only the IQSize and does not need estimate the network parameters
  - saves computation resources in bottleneck nodes in terms of computation and memory.
  - achieves better performance upon bandwidth variations and shows more robust queue performance.

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Thanks!

Q&A