Columbia University in the City of New York

AMuSe Adaptive Multicast Services

Bell Labs

Experimental Evaluation of Large Scale WiFi Multicast Rate Control

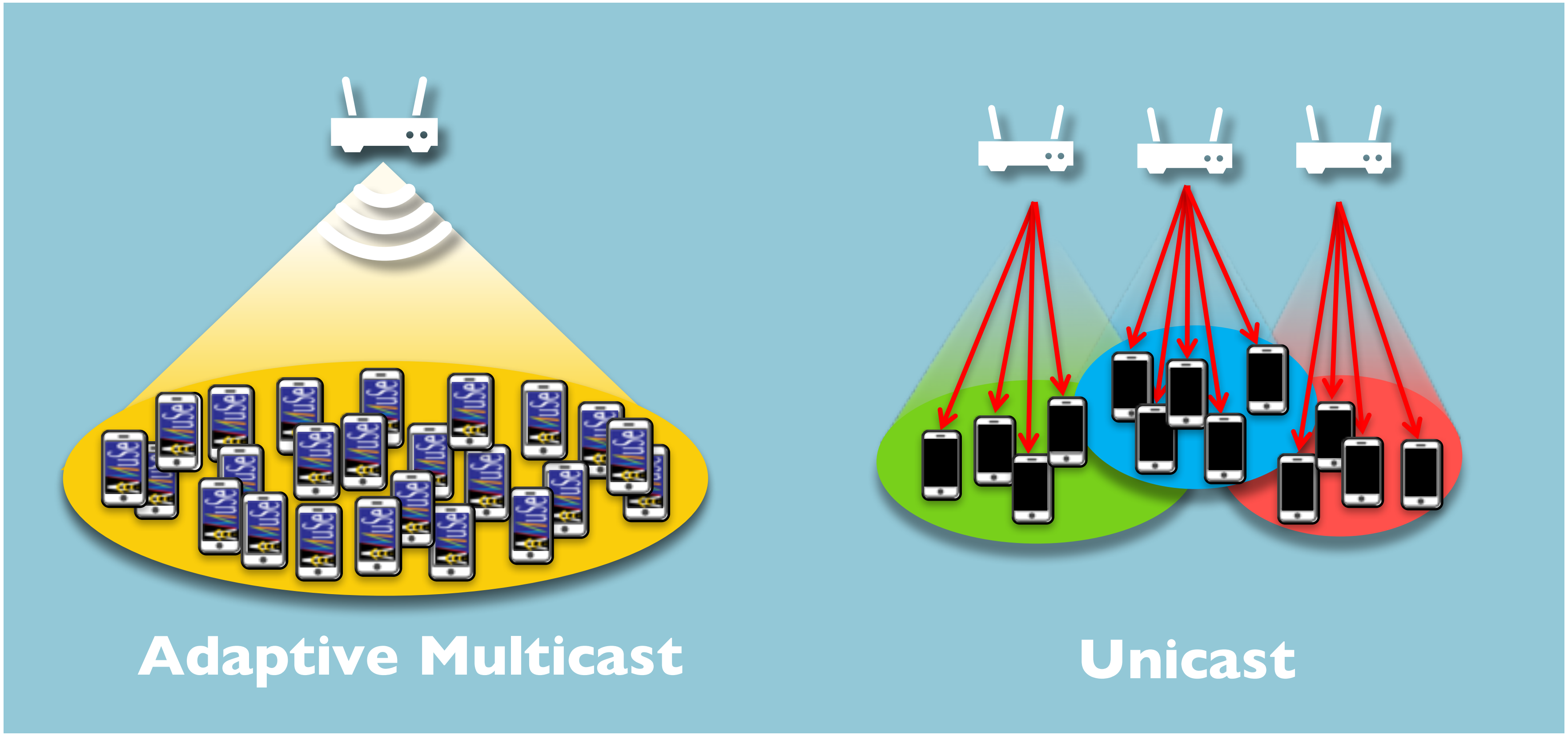
Varun Gupta*, Craig Gutterman*, Gil Zussman*, Yigal Bejerano°

*Electrical Engineering, Columbia University

°Bell Labs, Nokia

Objective & Motivation

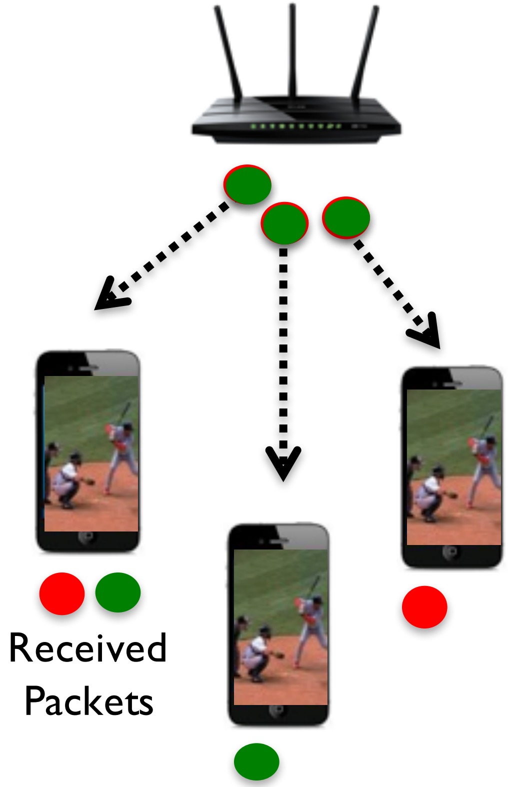
- Provide rich multimedia content to users in crowded areas
- Multicast substantially reduces bandwidth requirements
- Unicast: Large number of Access Points, frequency planning




JAM

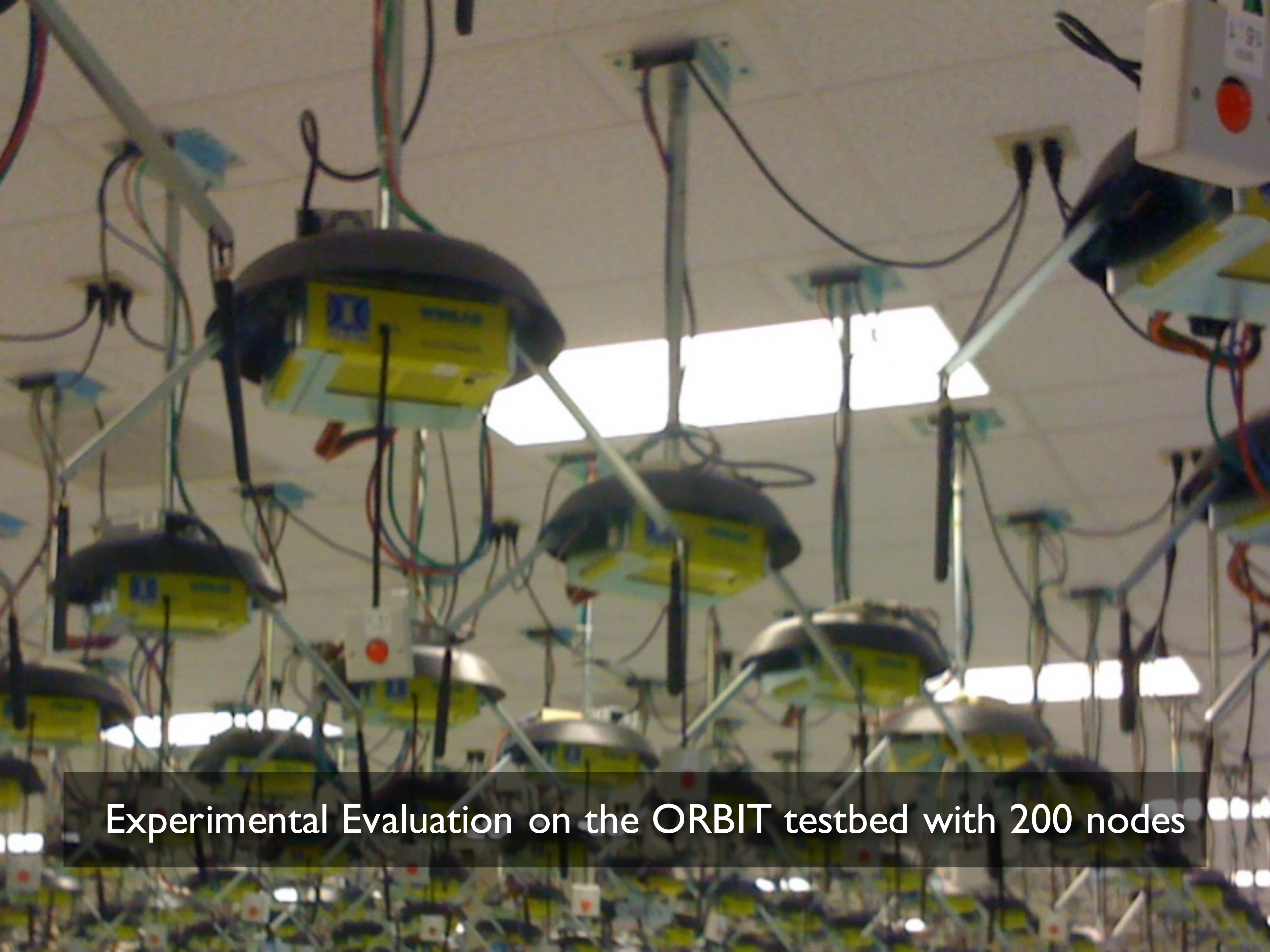
Multicast in WiFi

Unreliable packet delivery in multicast



- Access Point (AP) has no information of user channel conditions
- Individual packet ACKs → feedback flooding
- AP uses fixed low bit rates to ensure reliable delivery of packets
- **<u>Objective:</u>** Provide high throughput with Service Level Agreement (SLA) guarantees

- **Approach**
  - Practical solution for multicast to hundreds of users
  - **Adaptive multicast** with light-weight feedback mechanism
  - **Loss protection with FEC**, e.g., 15% redundancy
  - **Meet SLA requirements**, e.g., 85% packets to 95% of user
- **Implementation**
  - Application layer
  - Technology agnostic (WiFi, LTE)

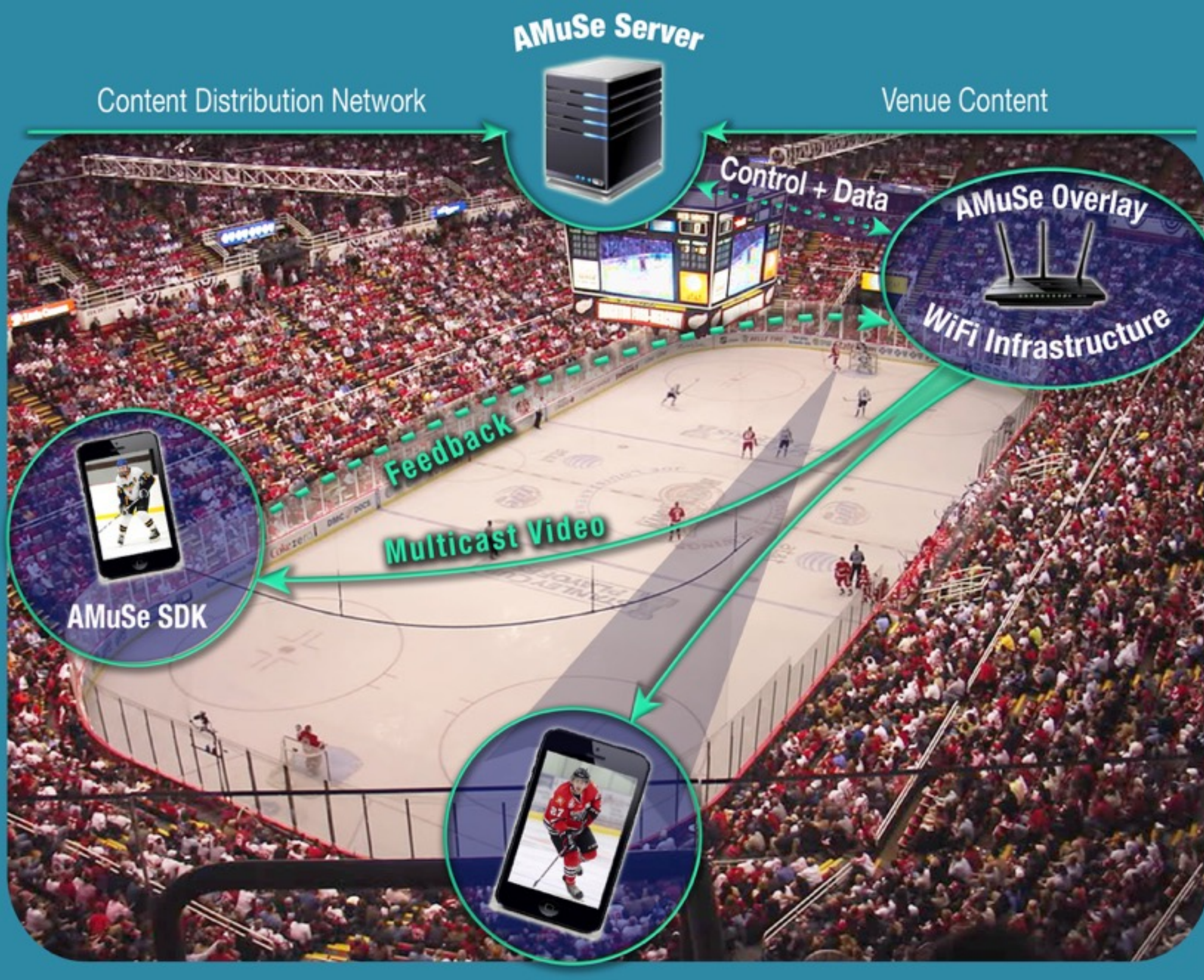

Experimental Evaluation on the ORBIT testbed with 200 nodes

Related Work

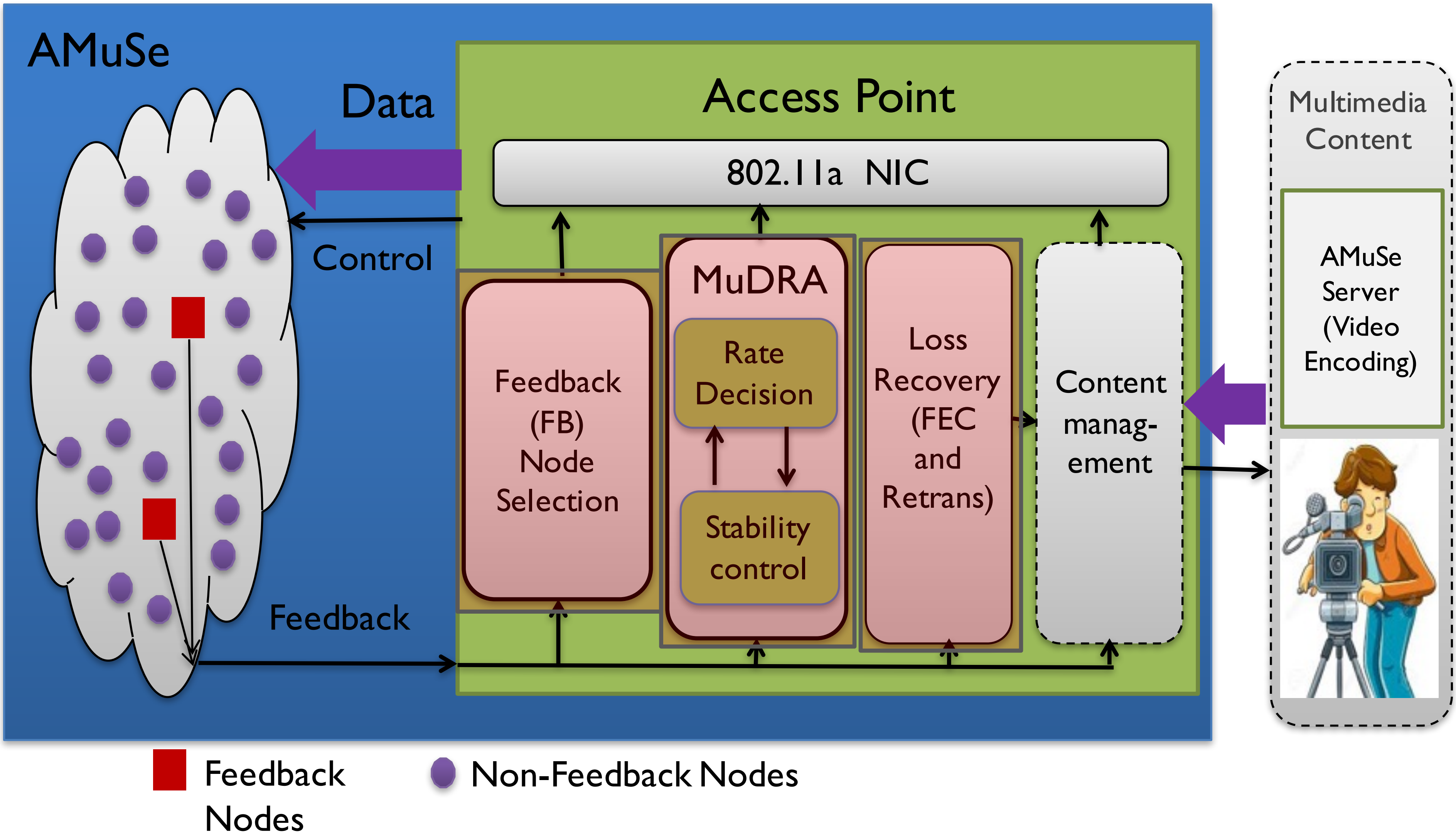
	Scalable	SLA Guarantees	High Throughput	Standards Compatible	Large Scale Evaluation
Basic WiFi Multicast	✓			✓	
Multicast with feedback from all users		✓		✓	
Unicast		✓		✓	
Leader Based Protocols: ACK based (Alay et. al, 2010) NACK based (Lim et. al, 2012)	✓				
Forward Error Correction (FEC) based			✓	✓	
AMuSe	✓	✓	✓	✓	✓

Overview

1. Background & Problem Definition
2. Related Work
3. **System Design**
4. Multicast Rate Adaptation Algorithm
5. AMuSe System Performance
6. Summary and Future Work


AMuSe Server
Content Distribution Network
Venue Content
Control + Data
AMuSe Overlay
WiFi Infrastructure
Feedback
Multicast Video
AMuSe SDK

Architecture



Experimental Environment

- 20x20 grid with 400 WiFi nodes at Rutgers University
- 4 external noise generators at corners

AP

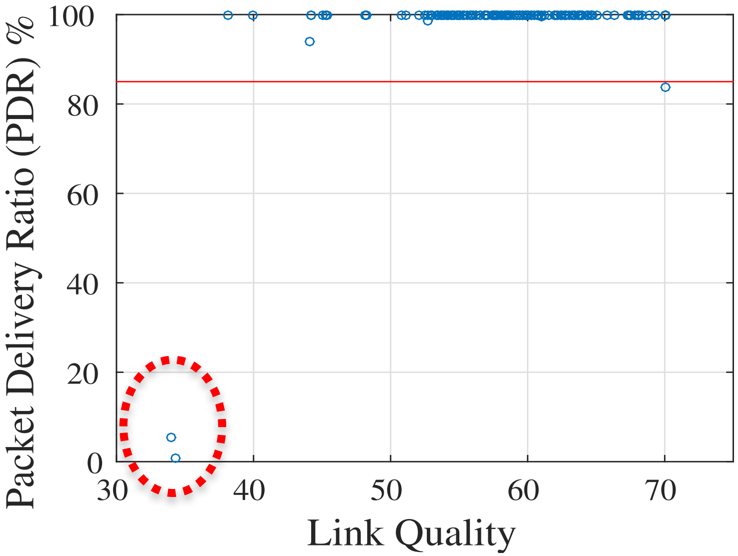
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1			52		41	36				41	36	32	31	36	28	31	29	32		25
2		54			32				35	34		35	39		34		34	30		
3	40	49		46	43	35	37		36	32	39	33			34	29	28		29	
4		38						33	36			35			31		33		28	25
5		36	50		39			32	31			35		29			37	29	33	
6		38	22		40		40	30									24	30	34	31
7	50				37	29	35	39			22	31	31	26	25		31	21		
8			44		33	47	30		28	30	32	33			24	29	27	36	27	
9			38		36	36		33	31	25		34			23	31	28	24		[illegible]
10	30	25		36	38			20				29		29		30	35			
11					33	27		26		31				32		28	[illegible]			29
12			39	34		33			27	33	25			29		[illegible]			25	
13				36					26	29	20	29		[illegible]		34			31	
14						25				24						29	27	32		27
15		30				41							33	25					27	
16			21				29	30		25	30			33				30		35
17			28			30	31		31	34	27				35		29	30		29
18		38			28				31	28	26			27	34	33				29
19	38		25		34	32	33			30	30			22			30			
20			27				28		31		32		21				25			27

LQ	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58

Link Quality (LQ), > 250 nodes

Parameter	Setting
Transport Protocol	UDP
Noise	On/Off AWGN
Transmit Power	0 dBm

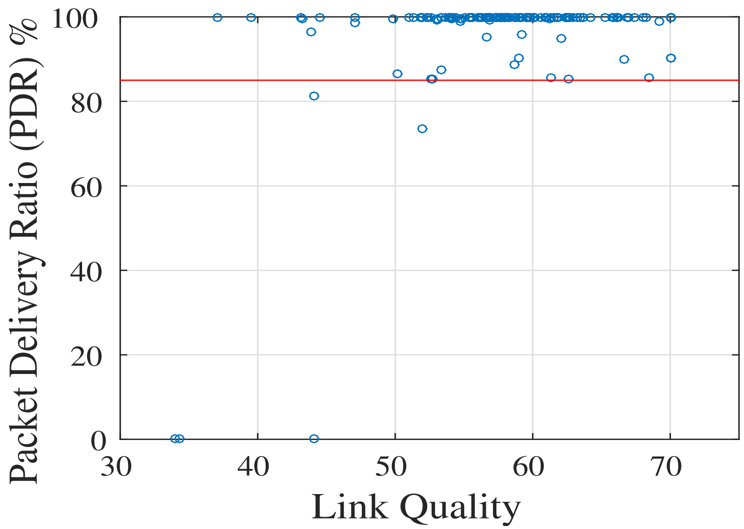
Key Observations



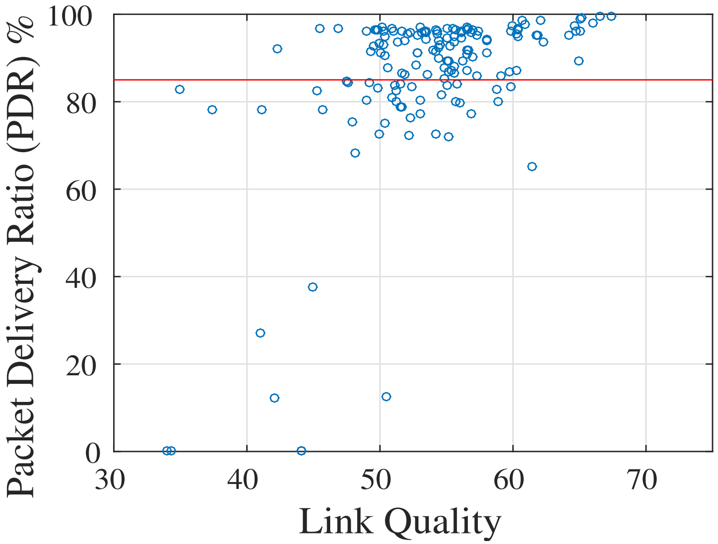
PDR vs. Link Quality at 6Mbps

- Even at low bit-rates, nodes with low Packet Delivery Ratio (PDRs) - **Abnormal nodes**
  - Impossible to have high network utilization while satisfying all users

Key Observations



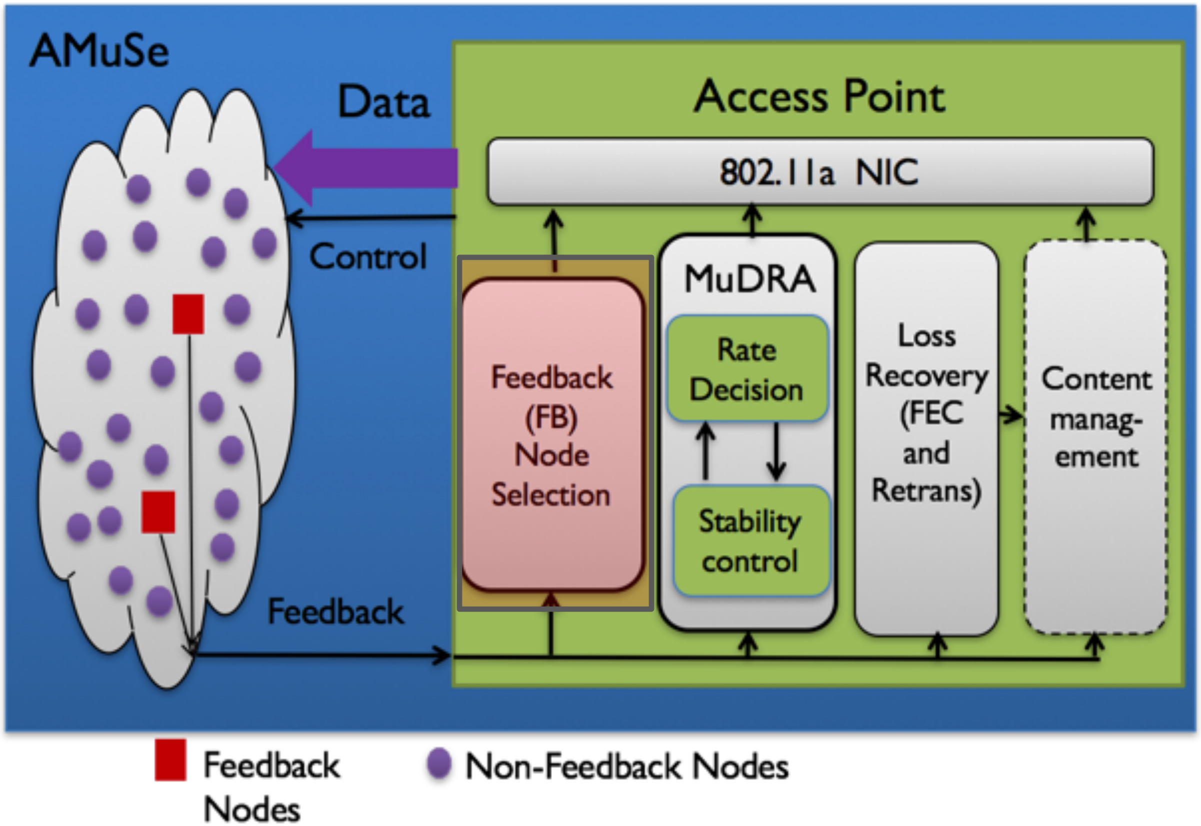
PDR vs. Link Quality at 36Mbps



PDR vs. Link Quality at 48Mbps

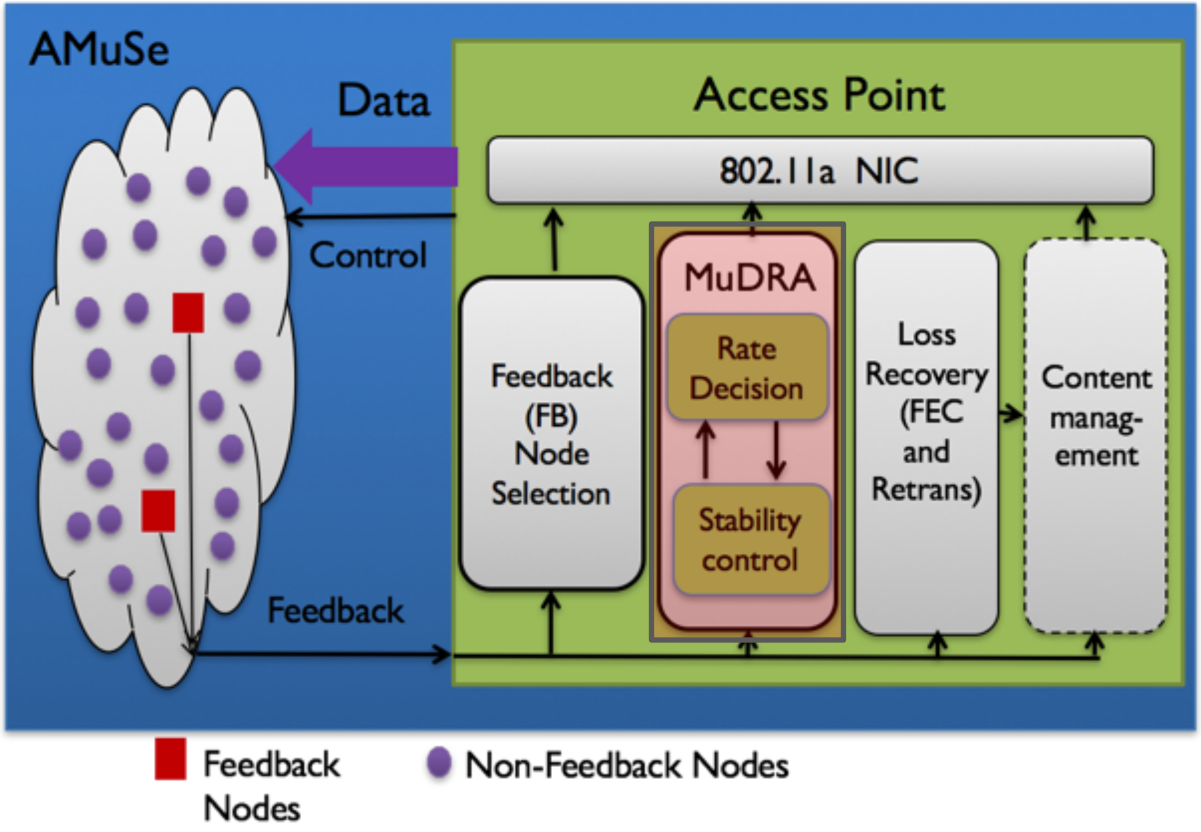
- **Target Rate** maximizes the network utilization while meeting SLA
- Nodes with same Link Quality (LQ) have significantly different PDRs
  - Receivers have different sensitivities, uncalibrated etc

Light Weight Feedback Mechanism



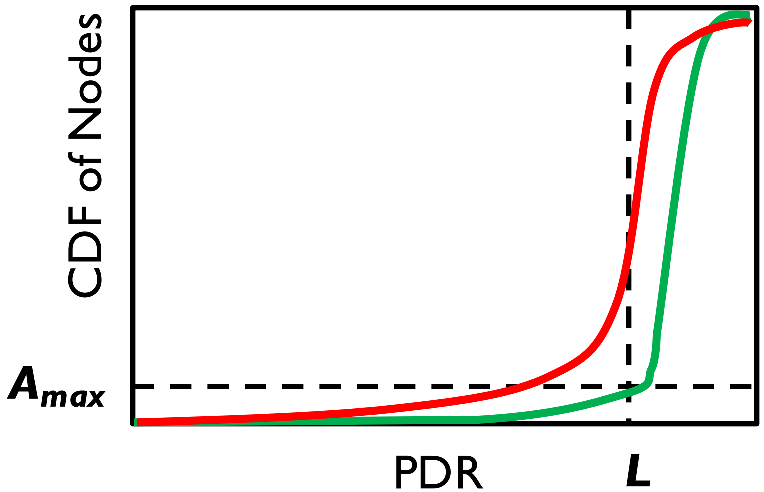
- Y. Bejerano et.al., *Scalable WiFi Multicast Services for Very Large Groups,* In Proc. IEEE ICNP'13, 2013.
- V. Gupta et.al., *Light-weight Feedback Mechanism for WiFi Multicast to Very Large Groups - Experimental Evaluation,* IEEE/ACM Transactions on Networking (to appear).

Multicast Dynamic Rate Adaptation (MuDRA)



MuDRA

- Satisfy SLA requirements while maintaining high throughput
  - At time *t*, number of nodes with *PDR* < *L* (denoted by A_t) should be less than A_{max}



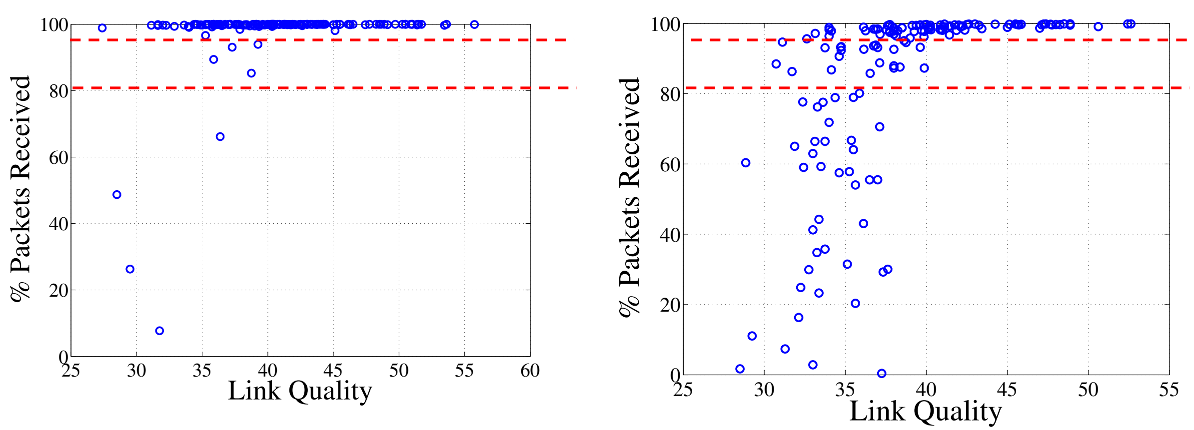
Constraint Violated → Reduce Rate

Target Rate

- Determine target bit-rate
  - **Why**: At rates > target rate, too many nodes receive low PDRs
  - **Challenge**: Link Quality is unreliable on commodity WiFi

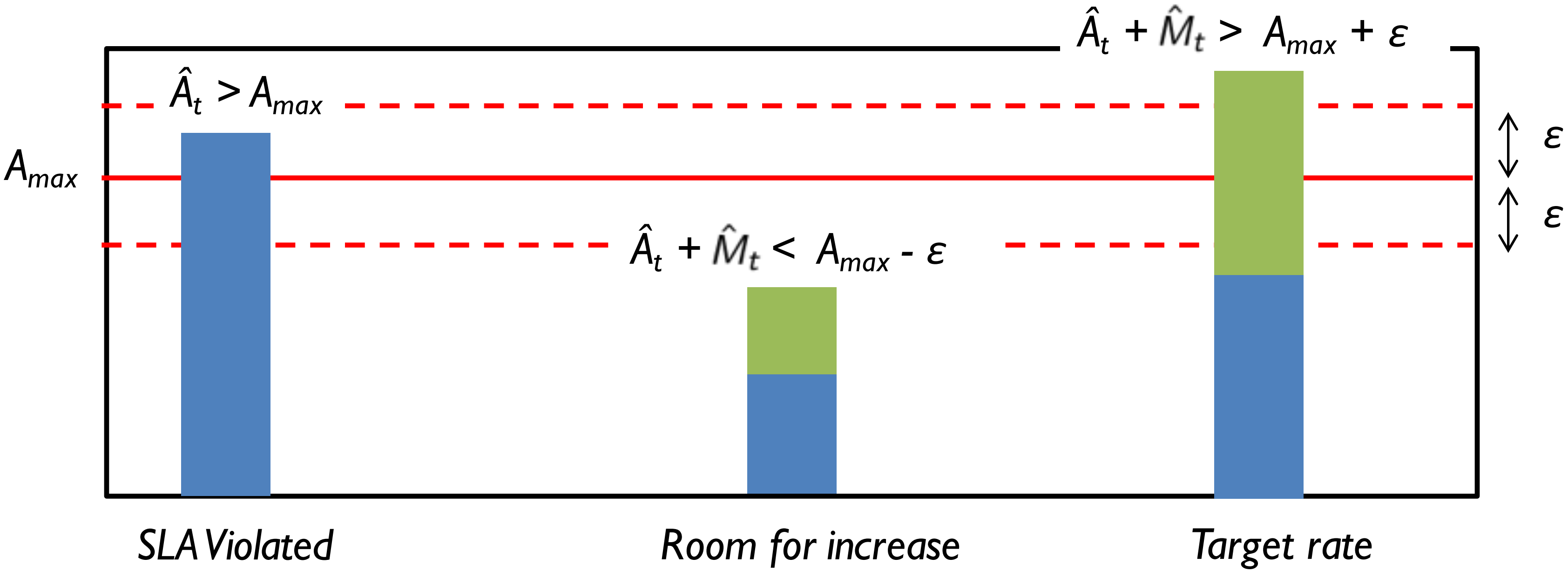
MuDRA Outline

- Property 1: If rate is below target rate then almost all nodes have PDR close to 100%
- Property 2: At the target rate, there is a threshold *H* such that nodes with *L* < PDR < *H* turn abnormal after a rate increase
  - Refer to these nodes as **mid-PDR nodes**
  - Rate increase requires 2-3dB higher SNR at the nodes



Conditions for Rate Change

- Abnormal nodes measured from feedback $\hat{A}_t$
- Mid-PDR nodes measured from feedback $\hat{M}_t$



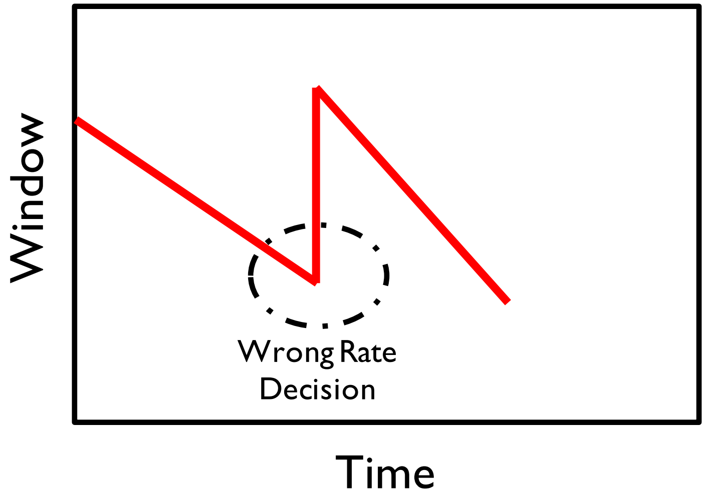
Lemma:

For *AMuSe* feedback scheme, $\hat{A}_t > \min(A_t, A_{max} + \epsilon)$, and $\hat{A}_t + \hat{M}_t > \min(A_t + M_t, A_{max} + \epsilon)$.

AMuSe feedback can always accurately test the rate change conditions

Ensuring Stability

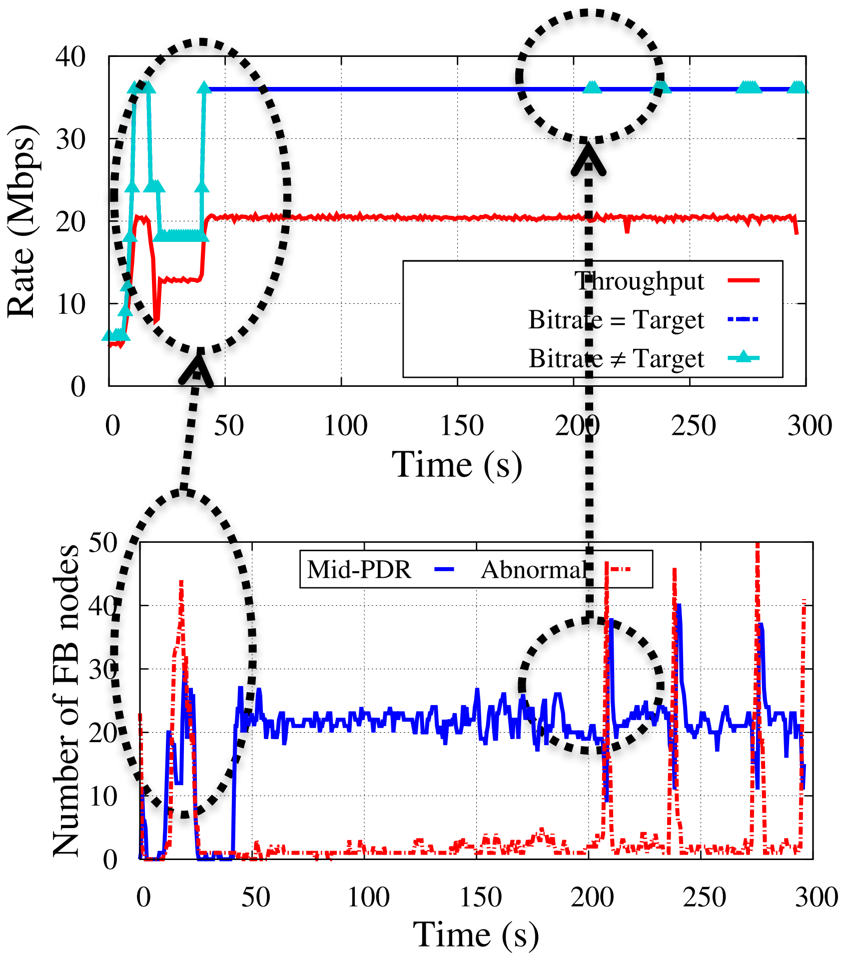
- Video streaming sensitive to rate changes
- Reducing bitrate maybe sub-optimal for short term
  - Fast-fading, bursty noise etc.
- Window-based mechanism to avoid frequent rate switches



MuDRA Evaluation

MuDRA Performance

- One instance of rate adaptation for a duration of 300s (170 nodes)



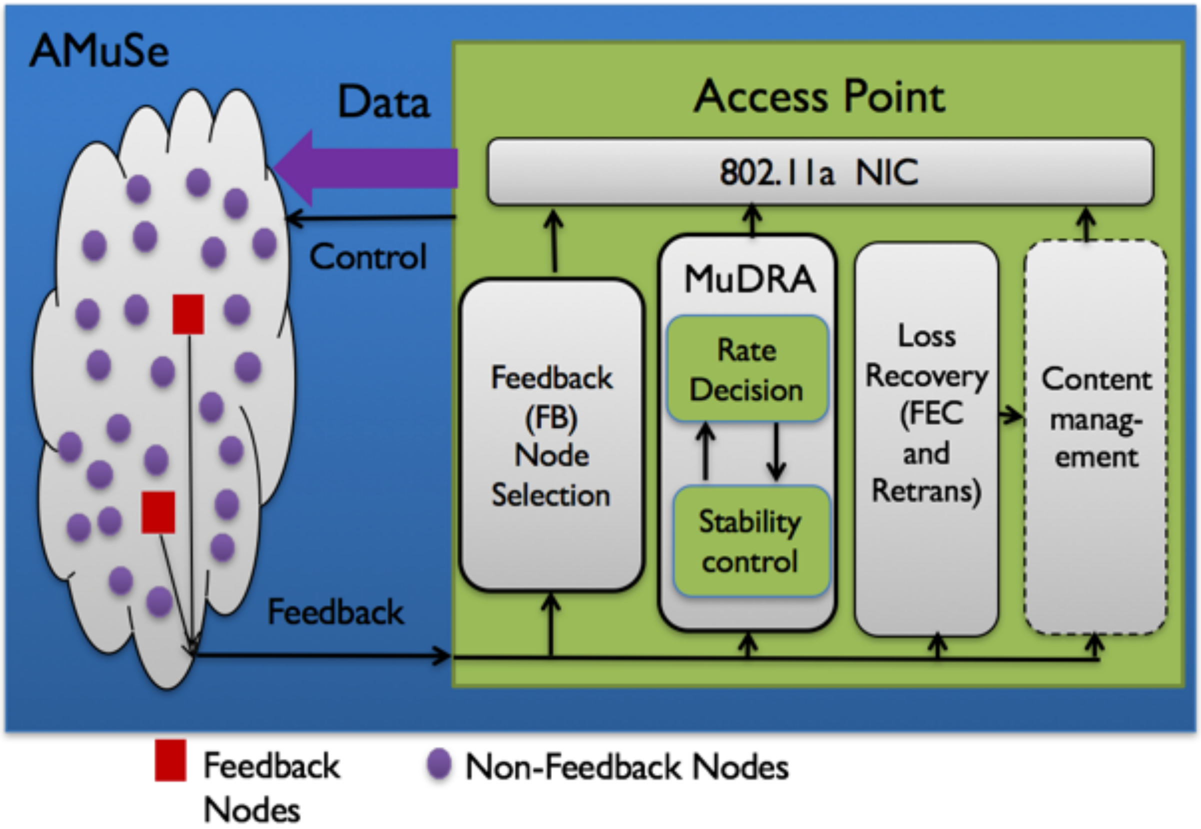
Bit-rate Adaptation at AP vs. time

- MuDRA converges fast to the **target rate**
- Rate is stable in the present of bursty interference

Mid-PDR and Abnormal nodes vs. time

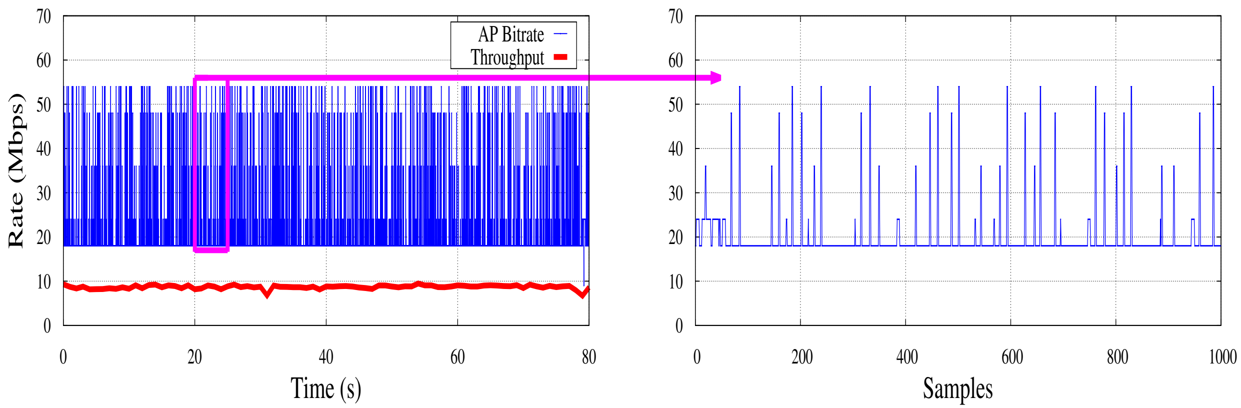
- Spike in number of abnormal nodes corresponds to not meeting target

System Performance



AMuSe vs. Other Schemes

- **Pseudo-multicast**
  - Unicast to the user with weakest link quality
  - Remaining users listen to the channel in promiscuous mode
  - Employ a unicast rate adaptation algorithm at the AP



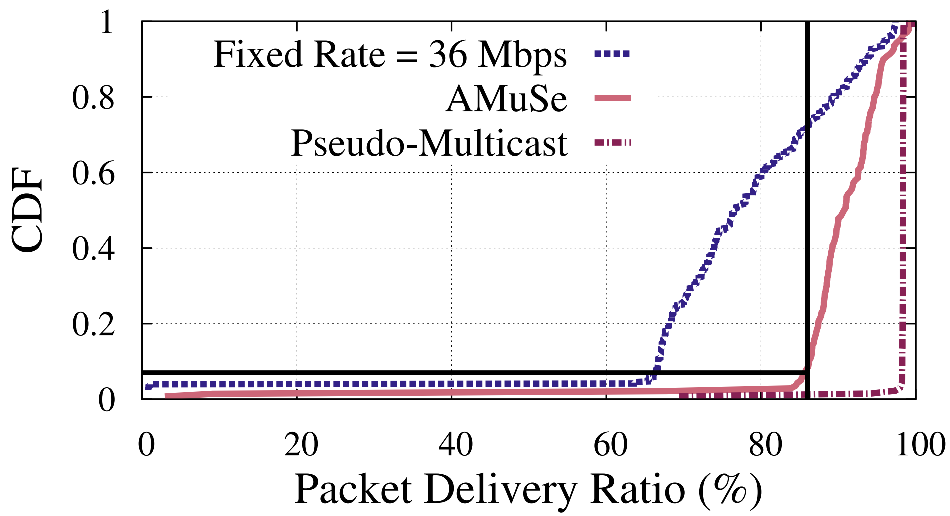
Performance of pseudo-multicast with the "Minstrel" rate adaptation algorithm

Throughput and Node Performance

- Pseudo-multicast: tuning multicast to the weakest receiver
- Several experimental runs over different days and times

	No Background Traffic	Background Traffic
Fixed Rate = 36 Mbps	20.42	13.38
AMuSe	19.45	11.67
Pseudo Multicast	9.13	2.36

Throughput measured at the AP

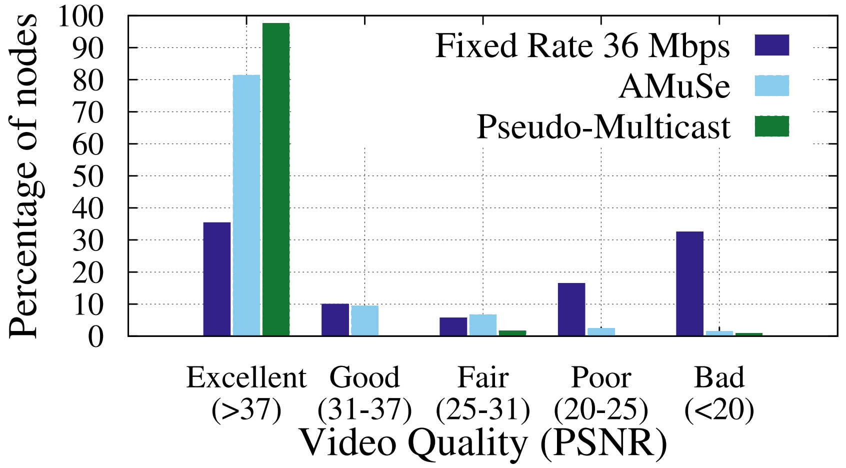


AMuSe satisfies SLA constraints

Video Performance

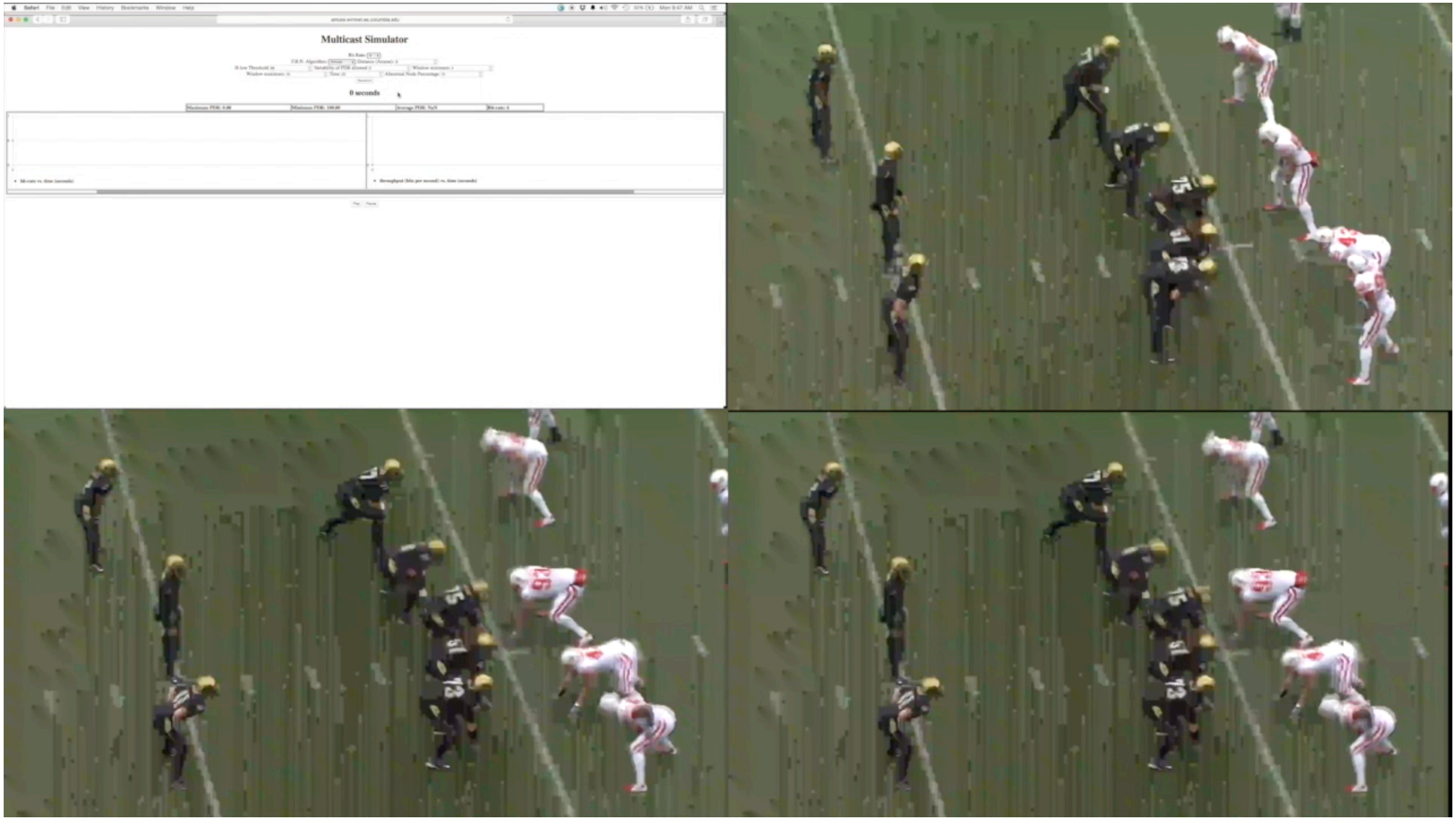
Video Quality	PSNR Range
Excellent	>37
Good	31-37
Fair	25-31
Poor	20-25
Bad	<25

User perception based on PSNR



Mapping video packets to wireless packets, 85% FEC

Demo Tomorrow



- V. Gupta et. al., "AMuSe: Large-scale WiFi Video Distribution – Experimentation on the ORBIT Testbed," in *Demo at IEEE INFOCOM'16*, 2016.
- V. Gupta et. al., "WiFi Multicast to Very Large Groups – Experimentation on the ORBIT Testbed," in *Demo at IEEE LCN'15*, 2015.

Summary & Future Work

- Summary
  - Design and implementation of AMuSe: a scalable and efficient system for WiFi multicast
  - Experimental evaluation on > 200 nodes
  - **Demonstration of video delivery through AMuSe to 200 nodes – Tomorrow 10:00am at Grand Ballroom A**

- Future Work
  - Scalable video coding techniques
  - Differentiating between interference types for rate adaptation

Thank You!

Email: varun@ee.columbia.edu

For more information:

wimnet.ee.columbia.edu/portfolio/amuse/