DyMo: Dynamic Monitoring of Large Scale LTE-Multicast Systems

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Talk Overview

- Industry Need: Video Distribution in Crowded Venues
- Past Experience - AMuSe for WiFi Networks
- The need for a new solution
- DyMo for monitoring LTE-Multicast (eMBMS)
- DyMo for Dynamic Management of Very Large Wireless Systems

Applications

- Stadiums: Bringing the home watching experience to stadiums
- Lecture Halls, Concert Halls, Amusement Parks
- Public Safety, Defense

Industry Need: Video Distribution in Crowded Venues

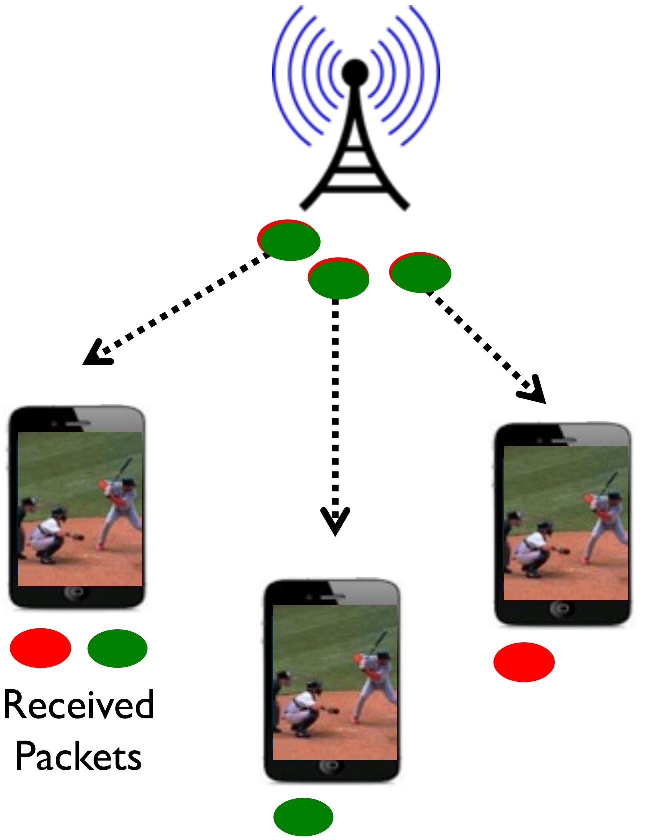
- Verizon's NFL Red Zone Channel - **$1 Billion** deal
  - Fans demand this service inside stadiums

- Video Multicasting in crowded venues a key selling feature of 5G
  - Even in 5G it will be a challenge to offer services without appropriate monitoring of user experience

- Verizon and other SPs form LTE-B (eMBMS) Alliance
  - "LTE-B is not limited to sporting events, and [VZ] intends to use it to push public safety warnings and weather updates, as well as IoT applications".

Multicast is offered without user experience monitoring and potentially poor service quality

Limitation of Wireless Multicast



- Unreliable packet delivery in multicast
- Base Stations (BSs) have no information of user channel conditions
- Individual ACKs → feedback flooding
- BSs use fixed low bit rates to ensure reliable delivery of packets

Objective: Providing high throughput multicast flows with Service Level Agreement (SLA) guarantees

Related Work

	Scalable	QoS Guarantees	High Throughput	Standards Compatible	Large Scale Evaluation
Basic WiFi Multicast	✓	✗	✗	✓	✗
Multicast with feedback from all users	✗	✓	✗	✓	✗
Unicast	✗	✓	✗	✓	✗
Leader Based Protocols: ACK based NACK based	✓	✗	✗	✗	✗
Forward Error Correction (FEC) based	✗	✗	✓	✓	✗
AMuSe	✓	✓	✓	✓	✓

Past Experience – AMuSe : Adaptive Multicast Services for WiFi Networks

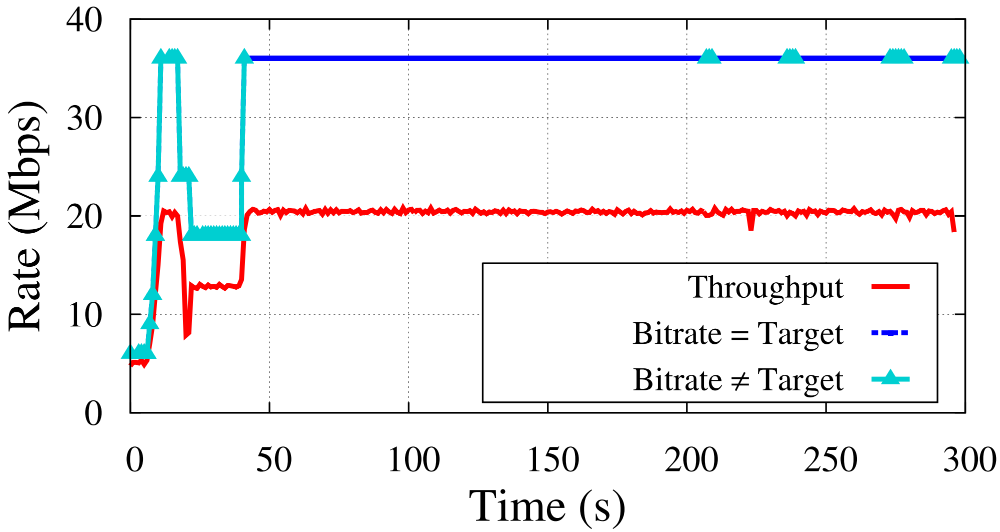
Requirements:

- **Scalability -** Practical multicast scheme for hundreds of users
  - Low uplink overhead
- **Service Level Agreement (SLA) guarantees**
  - e.g., 95% of users receive at least 85% of packets
- **Target Rate -** Operating at maximal multicast rate while meeting SLA constraints
- **Standard and technology compliance**
  - Application layer solution

Approach:

- **Adaptive multicast scheme** with **light-weight feedback** mechanism based on **a few feedback nodes**

ORBIT Testbed with 400 WiFi nodes

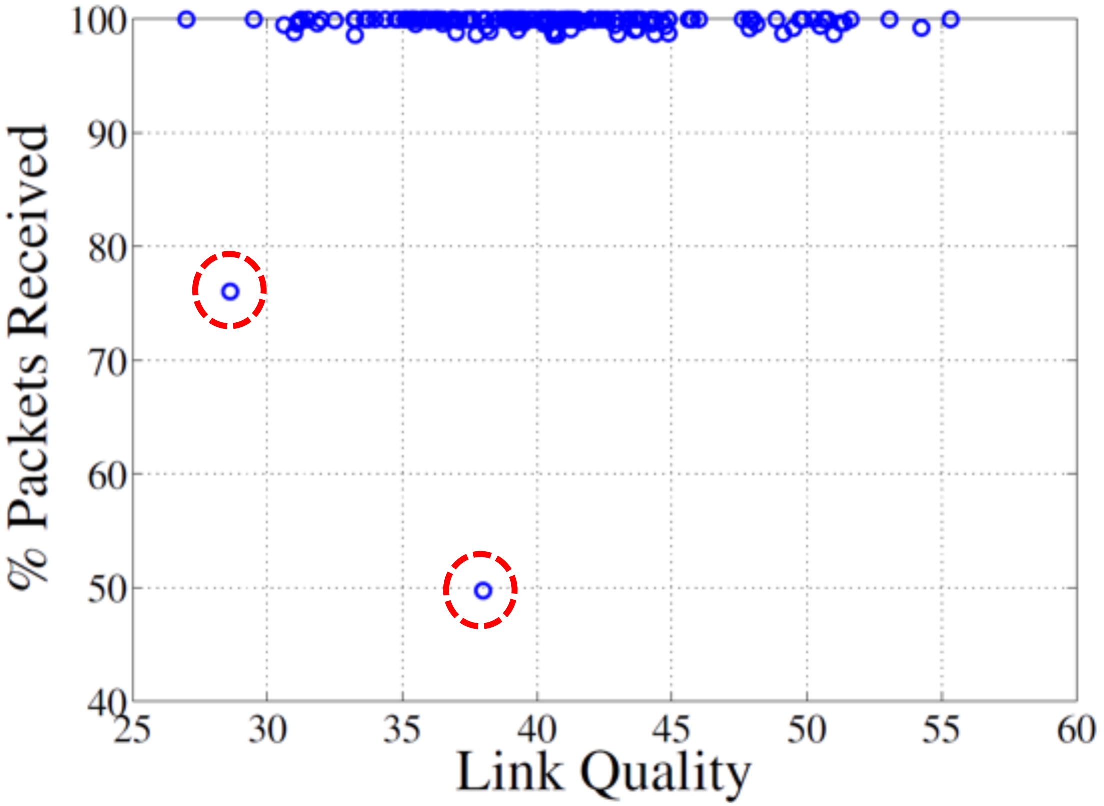


Converges to optimal bit-rate

Past Experience – AMuSe : Adaptive Multicast Services for WiFi Networks

Key Observations from Experiments:

- **It is practically impossible to have high network utilization while satisfying all users**
  - **Outliers** - Even at low bit-rates there are nodes with low Packet Delivery Ratio (PDR)
- **Nodes with the same Link Quality (LQ) may have significantly different Packet Delivery Ratios (PDRs)**



PDR vs. Link Quality at 6Mbps

A demo of AMuSe for WiFi Networks is presented at the

Fundamental Differences Between WiFi and LTE Multicast

WiFi-Multicast

- Unlicensed band
- MAC: CSMA/Collision Avoidance
  - No resource allocation
  - Service suffers from noise and collisions
- Each user associated with a single AP
  - Each AP sends a separate multicast flow
- User cannot accurately report CH quality
  - challenging to provide QoS guarantees
  - Solution based on experiments & heuristics

LTE-eMBMS

- Licensed band
- MAC: Centralized control with grants
  - Multicast (eMBMS) resource allocation
  - Service with limited noise
- Soft combine of multicast signals
  - All BSs send identical synchronized signal
- Users can report CH quality metrics (SNR)
  - **Challenge: meeting SLA requirements with minimal communication overhead**

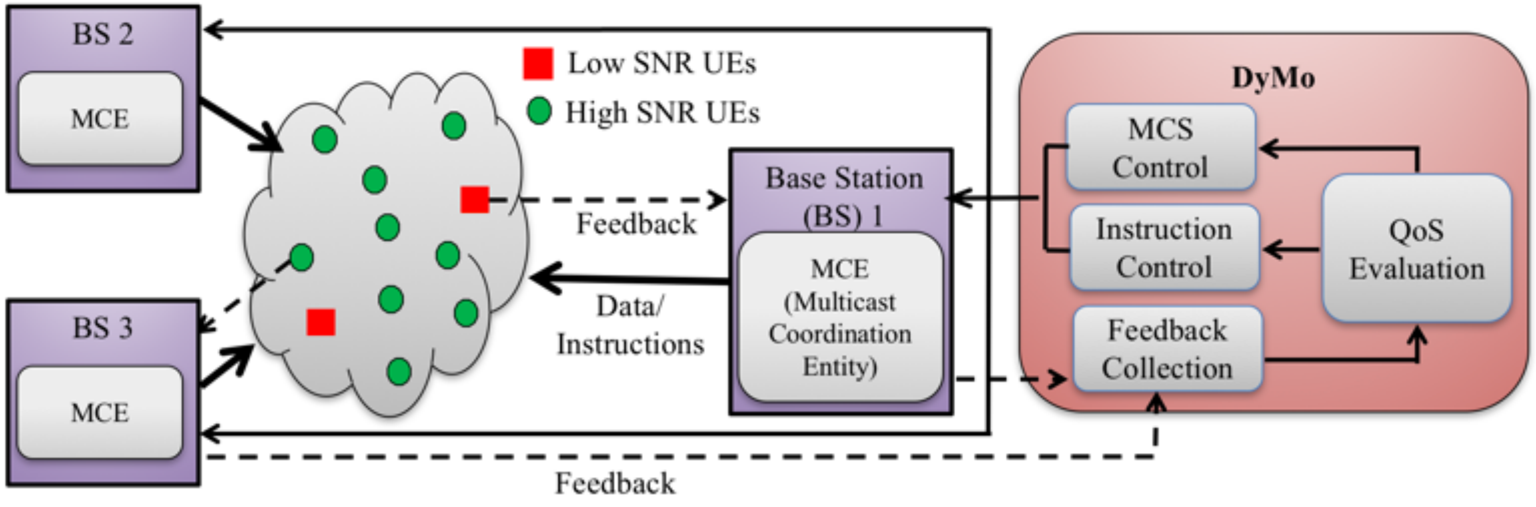
DyMo System Architecture

DyMo Server:

- Broadcasts instructions to all the UEs to control user feedback reports
- Analyzes the users' reports
- Determines parameter tuning, e.g., MCS, FEC, Video coding
- Maximizes network utilization within SLA constraints

DyMo-App on mobile devices:

- Send reports based on service quality and broadcasted instructions
- Unicast QoS reports containing eMBMS SNR data

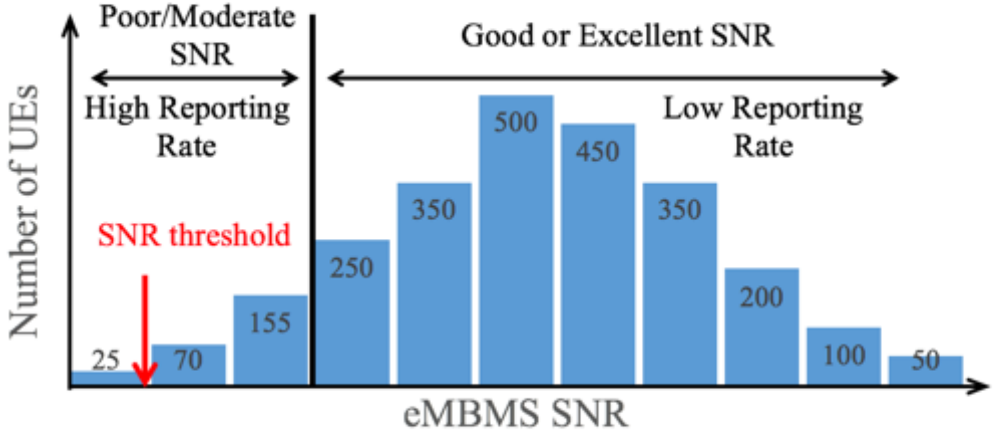


DyMo light-weight user feedback mechanism

Given: Fraction p of permitted outliers and report budget r.

Objective: SNR threshold, SNR(p) – Maximal eMBMS SNR s.t. at most p percent of the users suffer from lower SNR

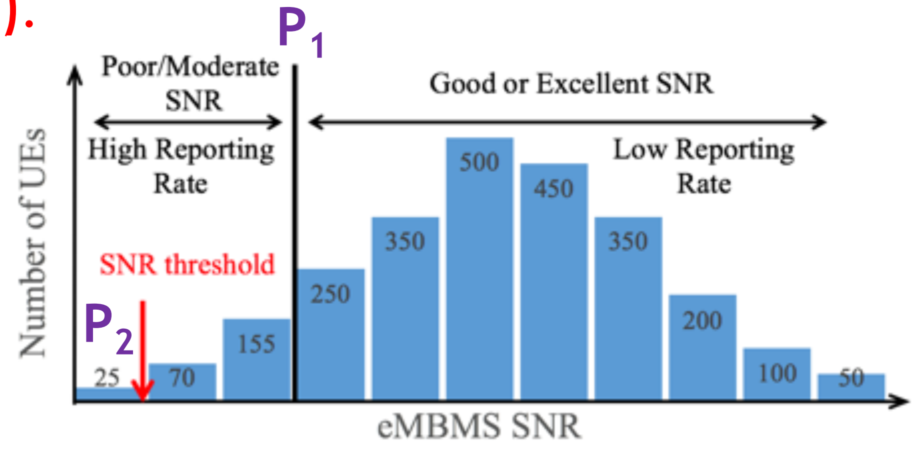
- **Server** uses eMBMS to broadcast instructions to all users
  - Specify conditions and report probability.
- **Receivers** with poor service send reports more frequently than users with good service.
  - E.g. receivers with SNR < 10db send report with prob. of 20%, receivers with SNR > 10db send report with prob. of 2%
- **Server** uses reports to infer service quality
  - eMBMS SNR distribution and SNR threshold
  - Determines optimal setting that meets SLA requirements



Dynamic learning of eMBMS SNR distribution

Algorithmic Approach

Challenge: Given fraction p of permitted outliers and report budget r, Minimize the estimation error of the SNR threshold, i.e., SNR(p).



Algorithm 1: Two-Step Estimation for the Static Case (m users)

- Select p_1 and p_2 such that $p_1 * p_2 = p$
- Select r_1 and r_2 such that $r_1 + r_2 = r$
- **Step 1:** each user reports with prob. r_1/m → estimate $SNR(p_1)$
- **Step 2:** each user with SNR < $SNR(p_1)$ reports with prob. $r_2/(p_1 * m)$ → $SNR(p_2)$ in range $[0, p_1]$ = SNR-Th

Optimal solution $p_1 = p_2 = \sqrt{p} \quad and \quad r_1 = r_2 = r/2$

Error upper bound $\epsilon_1 = \epsilon_2 = 3\sqrt{\sqrt{p}(1-\sqrt{p})/(r/2)}$

Algorithm 2: Iterative Estimation for the Dynamic Case (dynamic number of users)

Algorithmic details and performance analysis are provided in the paper.

Evaluation of DyMo

Evaluated schemes

Static – Fixed MCS

Optimal – Assume reports from all users

DyMo – Our SNR Threshold detection

Evaluation Scenarios (20K Users)

- **Stadium Environment**
- **Uniform with Failure Environment**

Evaluation metrics

SNR Threshold – maximal SNR s.t. at most p percent of the users suffer from lower SNR.

- **p = 0.1% from 20K users**→ at most 20 Users
- **Note:** SNR Th. → MCS and Spectral Efficiency

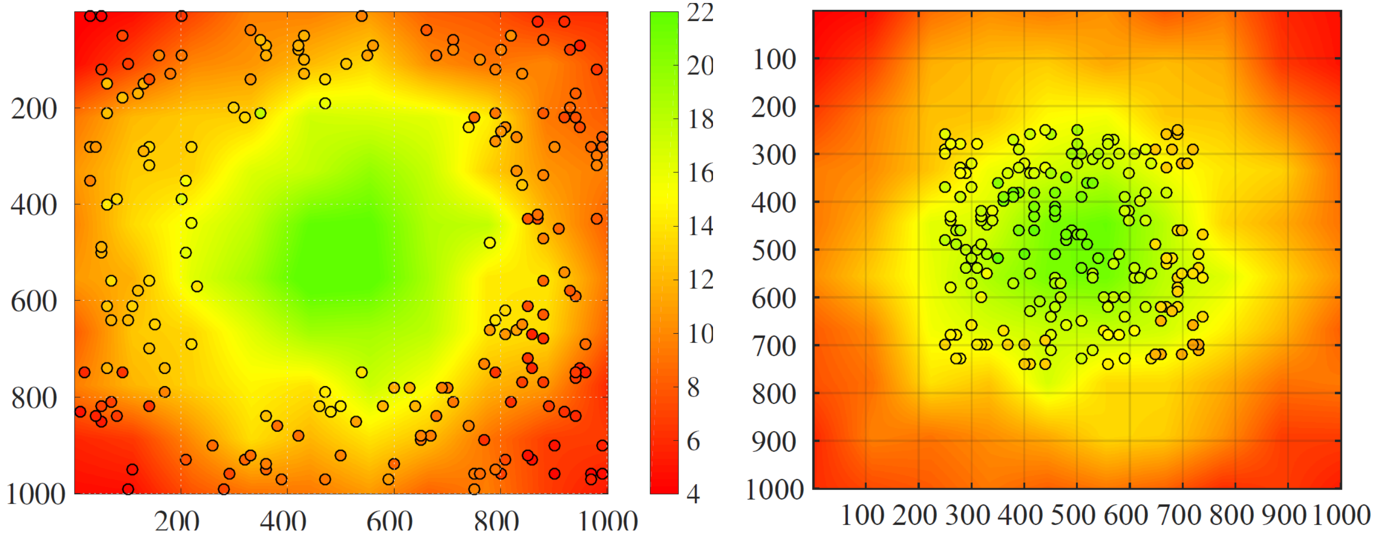
Outliers – Num of UE with SNR below SNR Threshold

- **DyMo measurement error < 0.1%**

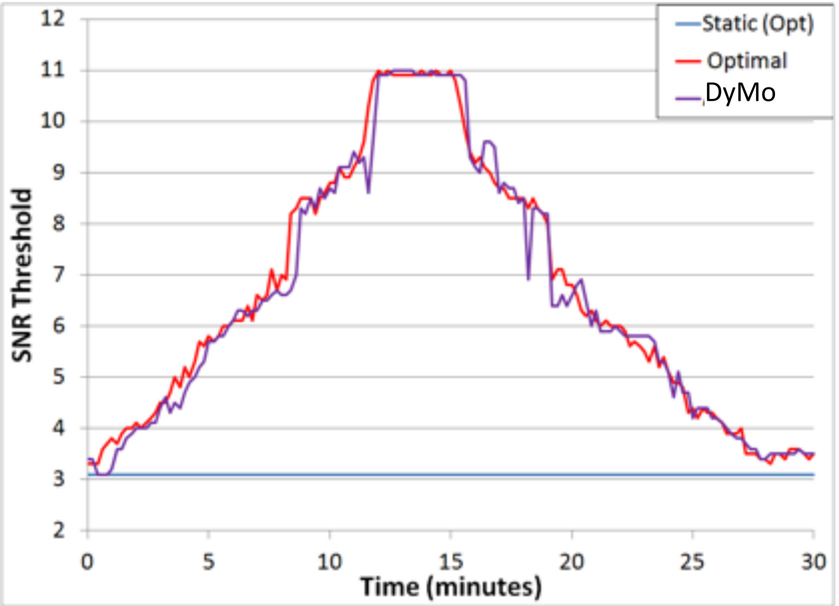
Number of Feedback Reports per second

- DyMo overhead **5 reports/sec** from **all users**
  - **60 messages per Report Interval**
- Optimal Scheme overhead **1600 reports/sec**

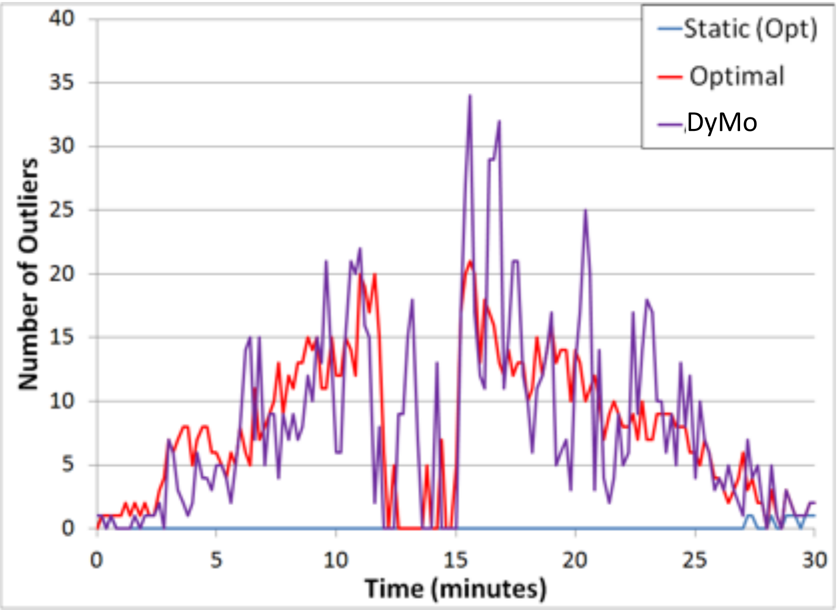
Evaluation 1: A Stadium



Service quality distribution in the venue and users' locations at time 0 (30) and 15.



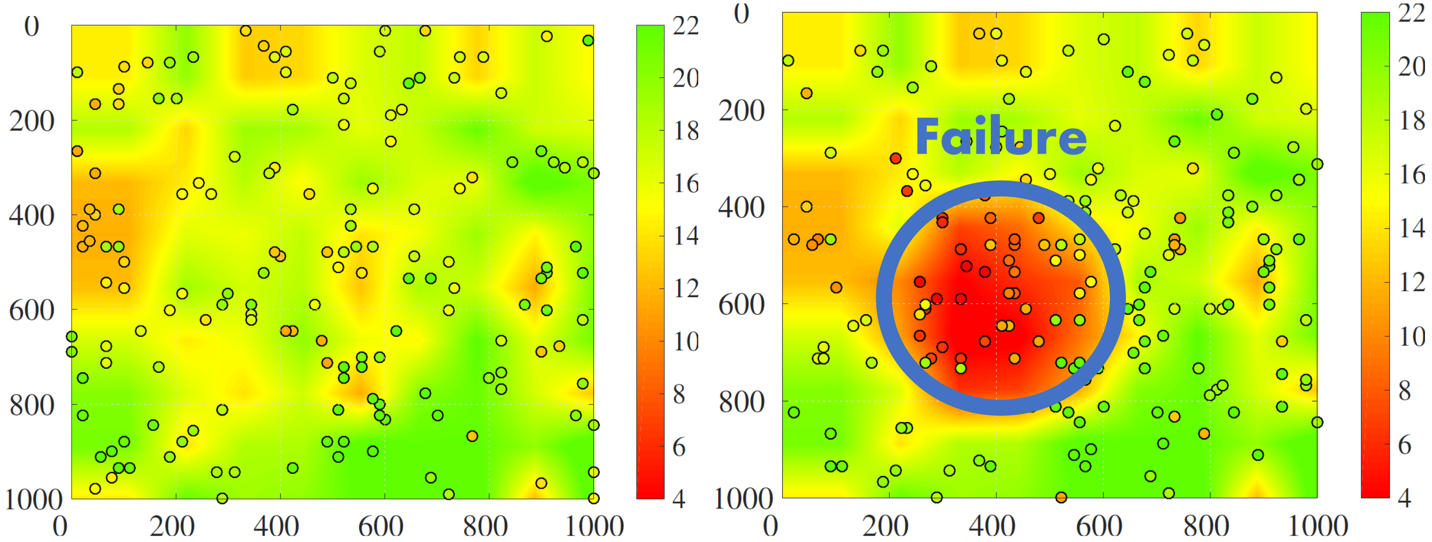
SNR threshold



Number of outliers

- Dynamic number of active UEs, **2K → 20K**
- Users' movement: edge → center and back

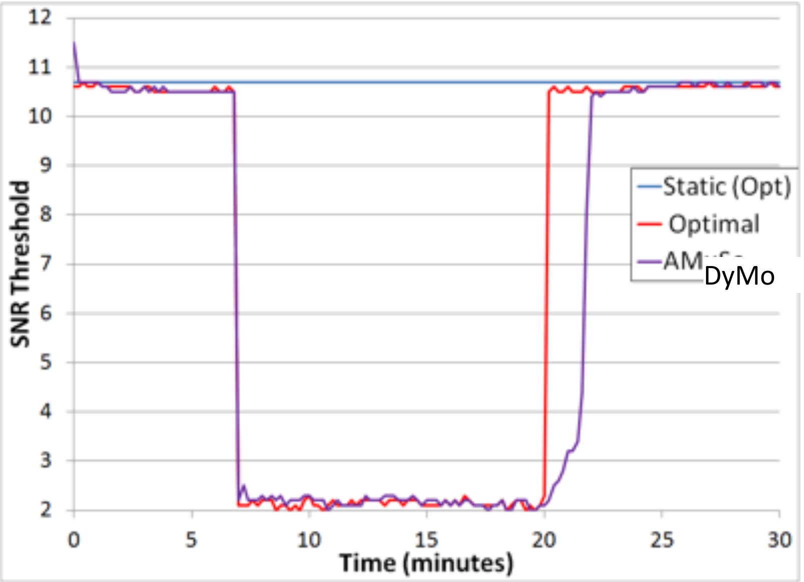
Evaluation 2: A Failure



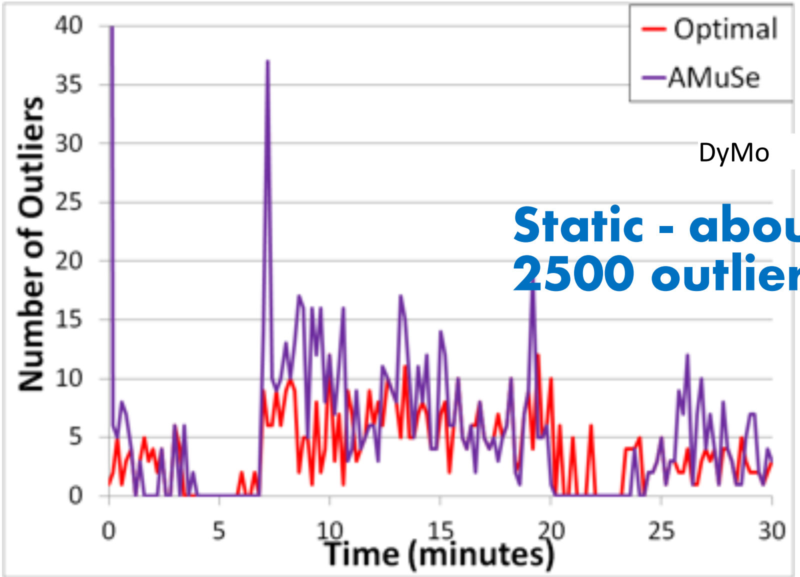
t=0 t=15

Service quality distribution in the venue and users' locations at time 0 (30) and 15.

- Dynamic number of active UEs, **10K→16K**
- Users' Movement: uniform → uniform



SNR threshold



Number of outliers

Many additional evaluation results are in the paper

What have we achieved?

Similar to unicast handshake,

Efficient and low overhead handshake
between the transmitter
and the multicast receivers

Conclusion

- Wireless multicast is an attractive approach for content distribution to very large groups.
- Traditional multicast services lack user feedback, therefore they are challenging to deploy and manage.
- DyMo provides pragmatic solution for simple, reliable and efficient management of wireless multicast services for WiFi and LTE-eMBMS.