PSCR 2020: THE DIGITAL EXPERIENCE







Multicast and Unicast in Serving Public Safety Traffic

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Outline



Introduction

First responders' experience in unicast and multicast

Summary

Unicast vs Multicast

Unicast

Multicast

Send multiple copies of the same content to multiple users

Send the same copy of the content to multiple users





Multicast could potentially save spectrum significantly.

Characteristics that Differentiate Public Safety Traffic



Leverage commercial technologies to meet public safety needs.

Decision Options from Previous Work*

- Multicast meets minimum throughput requirements.
- Multicast outperforms significantly in majority cases.



• Real time decision could be based on SINR and machine learning algorithm.



Multicast leaves 40 % resource available for other traffic.

*C. Liu, "Evaluating Multicast Capability in LTE Public Safety Networks," 2019 Public Safety Broadband Stakeholder Meeting, Chicago, July 9-11, 2019. **FR: First Responder;

SINR: Signal-to-Interference-plus-Noise Ratio.

Communication Chain



MIMO: Multiple-Input and Multiple-Output BLER: BLock Error Rate CQI: Channel Quality Indicator MCS: Modulation and Coding Scheme

Explore each component along the communication chain and quantify its impacts on resulting performance.



LTE network on 700 MHz public safety spectrum, MIMO 8x4, Inter-Site-Distance(ISD) 500 m.

Scenario Illustration



Scenario Illustration



*MBSFN: Multimedia Broadcast Multicast Service Single Frequency Network.

Communication Chain



Explore each component along the communication chain and quantify its impacts on resulting performance.



Slightly higher signal levels in multicast.

Wideband Interference



Significantly lower interference in multicast.

Illustration with Finer Granularity





• SINR is higher in multicast.



-1.24

For unicast, SINR decreases with increasing number of layers.

5.25

-7.54

• For unicast, outage increases with increasing number of layers.

6.94

Layer 2

SINR is higher in multicast.

3.09

6.61

10.81

20.19



• For unicast, SINR decreases with increasing number of layers.

• For unicast, outage increases with increasing number of layers.

SINR is higher in multicast.



• For unicast, SINR decreases with increasing number of layers.

• For unicast, outage increases with increasing number of layers.

SINR is higher in multicast.

Optimized Rank in Unicast



Transport Block SINR in Unicast



*TB: transport block

Transport Block SINR



Unicast TB 2

Multicast

3.06

21.50

8.41

24.12

17.30

52.37

Communication Chain



Explore each component along the communication chain and quantify its impacts on resulting performance.

Transport Block CQI



CQI Distribution



Multicast CQI Distribution by Cells





4

 $\times 10^4$











imper of Samples ×104

Different CQIs across cells in multicast.

Communication Chain



Explore each component along the communication chain and quantify its impacts on resulting performance.

Resource Efficiency



Resource efficiency (bits/symbol)	Mean	SD	Min	5 %	25 %	50 %	75 %	Мах
Unicast TB 1	1.92	0.59	0.37	1.04	1.54	1.88	2.18	4.64
Unicast TB 2	2.16	2.03	0.00	0.03	0.32	1.65	3.72	9.31
Multicast	4.98	0.71	1.57	3.38	4.73	5.24	5.51	5.55

Resource Efficiency 1000 1000 15 Unicast 15 Multicast 10 Y position (m) 10 Y position (m) 500 500 Bits / Symbol Bits / Symbol 5 5 0 0 0 0 -1000 -1000 -500 -500 0 0 X position (m) X position (m)

Resource efficiency (bits/symbol)	Mean	SD	Min	5 %	25 %	50 %	75 %	Мах
Unicast	4.08	2.54	0.37	1.18	2.16	3.34	5.60	13.95
Multicast	4.98	0.71	1.57	3.38	4.73	5.24	5.51	5.55

- Unicast uses the resource much more efficiently in some areas than in other areas.
- Multicast has relatively consistent resource efficiency across the area.
- Multicast improves resource efficiency at cell edge.



Communication Chain



and quantify its impacts on resulting performance.

Outage Probability - Coverage



Potential Throughput



- In unicast, first responders could experience excellent throughput in some areas, and may suffer in some other areas.
- In multicast first responders' experience would be relatively consistent.
- First responders have the possibility to experience much higher throughput in unicast than in multicast.
- Multicast improves potential throughput at cell edges.

Potential Throughput Distribution



Actual Throughput



Actual unicast throughput is mainly limited by # first responders due to spectrum sharing. Actual multicast throughput is mainly limited by the minimum CQI among all first responders.

Communication Chain



- Multicast improves outage probabilities.
- First responders have the possibility to experience much higher throughput in unicast than in multicast.
- Multicast leads to higher actual throughput when # FRs is high.

Scenario Illustration









Do the results hold for public safety incidents with small footprints?

Study on scenario within one cell.

Scenario within One Cell



No constructive signals from other cells for multicast. More interfering cells.

Communication Chain



Explore each component along the communication chain and quantify its impacts on resulting performance.

One Cell Scenario – Transport Block SINR



One Cell Scenario – Transport Block CQI



13

42 15.00

14.91

One Cell Scenario – Resource Efficiency



- Unicast uses the resource much more efficiently in some areas than in other areas.
- Multicast has relatively consistent resource efficiency across the area.
- Multicast improves resource efficiency at cell edge, less improvements with area size 1 cell.

One Cell Scenario - Outage Probability



Multicast with 1 cell has less improvement than with 21 cells.

One Cell Scenario - Potential Throughput



• In unicast, first responders would experience excellent throughput in some areas, and may suffer in some other areas.

- In multicast first responders' experience would be relatively consistent.
- First responders have the possibility to experience much high throughput in unicast than in multicast.
- Unlike the 21-cell case, multicast with 1 cell NO LONGER improves potential throughput at cell edges.

One Cell Scenario - Actual Throughput



Actual unicast throughput is mainly limited by # first responders due to spectrum sharing. Actual multicast throughput is mainly limited by the minimum CQI among all first responders.







The same results apply to both large and small public safety incidents.

Summary



We studied unicast and multicast in serving public safety traffic.





The results allow first responders and network operators to predict user experience and to configure the network to better serve public safety traffic.



While the analysis was based on 700 MHz public safety spectrum, the results can be easily extended to other spectrums.



Next steps - explore multicast in 5G New Radio.

References

- C. Liu, C. Shen, J. Chuang, R. A. Rouil, and H. A. Choi, "Throughput Analysis between Unicast and MBSFN from Link Level to System Level," IEEE 90th Vehicular Technology Conference (VTC-Fall), 2019.
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- C. Liu, C. Shen, J. Chuang, R. A. Rouil, and H. A. Choi, "Evaluating unicast and MBSFN in public safety networks," submitted, 2020.
- S. Feng, C. Liu, C. Shen, H. A. Choi and R. A. Rouil, "An Effective and Efficient Dynamic eMBMS Multicast Grouping Scheduling Algorithm in MBSFNs for Public Safety Scenarios," IEEE Access (accepted).





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50