



# Layered Media Multicast Control (LMMC)

## Error Control

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# Distributing Multimedia Content over Hybrid Wired and Wireless Networks

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- CCN

- Resource Allocation
- Error Control
- Channel Modeling
- Flow Control
- Congestion Control

- SP & Comm

- JSCC
- Transmission and Space-Time Coding
- Handoff
- Power Optimization



# CCN Scope

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- Work Done

- Rate Allocation & Partitioning (RAP)
- Error Control (EC)
- Flow Control (FC)

- Future Work

- Congestion Control
- Wireless Networks Error Control
- LMMC Dynamic Rate Analysis
- Handoff & QoS



# SP & Comm Scope

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- Work Done

- JSCC for Wireless Systems
- Utilizing Multiple Transmit Antennas
- Power Optimization of Memoryless Systems

- Future Work

- Analytical Channel Modeling
- Power Optimization of Wireless Systems w/ Memory
- Video Summarization

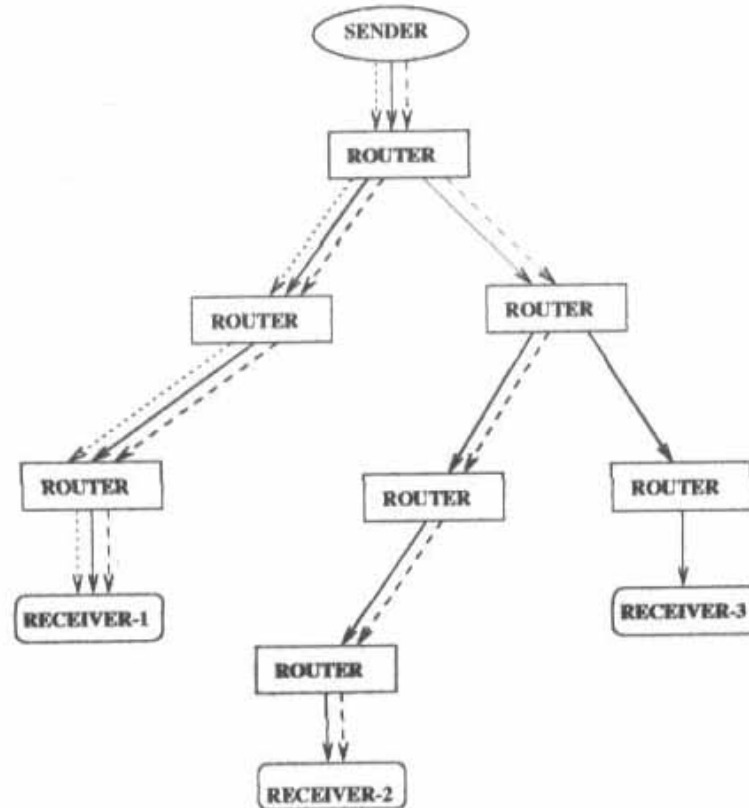


# Specific CCN Challenges

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- Real-Time Delay Constraints
- Receiver Heterogeneity
- Intra-Session Fairness
- Quality of Service
- Inter-Session Fairness
- Network Resource Sharing

# Multimedia Content over Multicast Networks





# Multimedia Content over Multicast Networks

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- Replicated Media (RM) Approach

- Independent Replicated Multicast Groups
- B/W Overhead
- Protocol Simplicity

- Layered Media (LM) Approach

- Successively Refinable Multicast Groups
- B/W Efficiency
- Protocol Complexity



# Background Work

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- Media Content over Mcast
  - S. Deering, Stanford
- Intra-Session & Inter-Session Fairness
  - M. Ammar, Georgia Tech
- Multicast Layering Fairness
  - D. Rubenstein, Columbia
  - J. Kurose, UMass
- Rate Allocation & Partitioning
  - S. Lam, UT Austin
  - J. Bolot, UCB
- Error Control
  - I. Rhee, NCSU
  - J. Kurose, UMass
- Feedback Implosion
  - D. DeLucia, USC
  - J. Garcia-Luna, UCSC
- Receiver Centric Models
  - S. McCanne, UCB
  - M. Ammar, Georgia Tech
- Flow and Congestion Control
  - S. Floyd, UCB
  - B. Srikant, UIUC



# Error Control (EC)

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- Problem Scenario:  
Delivering Multimedia Content from One Source to N Receivers through K Multicast Data Groups.
- Problem Definition:  
Given the Redundancy Requirement of Each Receiver, Address the Error Control Issue for Each Data Group by Assigning Multiple Redundancy Layers to Each Data Group.
- Layer Redundancy Rates of Group k  
 $r_1, r_2 - r_1, r_3 - r_2, \dots, r_{V_k} - r_{V_k-1}$
- Problem Formulation:  
Find a partitioning of  $N_k$  receivers of Group k into  $V_k$  redundancy groups  
$$\Omega_k = \{R_1 | \dots | R_{V_k}\}$$
  
optimizing wasted bandwidth of redundancy relying on a hybrid ARQ-FEC encoding.



# LMMC EC Formulation

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- Optimization Problem

$$\min_{\mathbf{r}_1, \dots, \mathbf{r}_{V_k}} ECW_k =$$

$$\min_{\mathbf{r}_1, \dots, \mathbf{r}_{V_k}} \sum_{j=1}^{V_k} \sum_{i=1}^{B_k} w_i (\mathbf{r}_j - i)$$

$$\text{Subject To: } \mathbf{r}_{V_k} \leq B_k$$

$w_i$  is associated with the receivers

requesting redundancy  $i$ ,  $\sum_{i=1}^{B_k} w_i = N_k$

Formulation is implosion free!



## LMMC 2-Phase EC Solution (1)

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- Phase 1:

Lemma (II.1) of LMR Work shows that for a *fixed partitioning* the optimal redundancy rates of each group are calculated as

$$\mathbf{r}_j^* = \max_{i \in R_j} r_i, \quad j \in \{1, \dots, V_k\}.$$



## LMMC 2-Phase EC Solution (2)

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- Phase 2: For A Set of Given Redundancy Rates Obtain the Best Partitioning Strategy.
- For  $\Omega_k = \{R_1 | R_2\}$  and  $G_k = \{1, \dots, M_1 | M_1 + 1, \dots, M_2\}$  the best partitioning strategy is
  - Move Receiver  $s$  with Redundancy  $r_s$  and Receivers w/ Greater Redundancies from  $R_1$  to  $R_2$  if

$$M_1 (r_{M_2} - r_{M_1}) < (s - 1) (r_{M_2} - r_{s-1})$$

- Move Receiver  $t$  with Redundancy  $r_t$  and Receivers w/ Lower Redundancies from  $R_2$  to  $R_1$  if

$$M_1 (r_{M_2} - r_{M_1}) < t (r_{M_2} - r_t)$$



# LMMC Iterative Error Control Algorithm

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- Start from an Initial Partition
- Do {
  - Phase I: Obtain Optimal Redundancy Rates of Each Partitioning
  - Phase II: Repartitioning All Neighboring Redundancy Groups for the Rates of Phase I
- } While  $\left(\frac{|ECW_1 - ECW_2|}{ECW_1} < \mathbf{d}\right)$



# Integration with LMMC RAP

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- Define Coefficient of Redundancy for Group  $G_k$

$$CoR_k \equiv \frac{B_k}{B_k + \mathbf{r}_{V_k}}$$

- Recall LMMC-RAP Formulation for Group  $G_k$

$$\max_{g_k} IRFA_k = \max_{g_k} \sum_{i \in G_k} \frac{(2+a)r_i g_k}{g_k^2 + a r_i g_k + r_i^2}$$

$$\text{SubjectTo: } g_k \leq BWA_k$$

- Multiply  $BWA_k$  by  $CoR_k$  in Every Iteration to Introduce a Combined RAP-EC Algorithm.



# An Alternative Layering Solution

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- I. Rhee et al. at NCSU Solve the Same Problem Proposing Layered Multicast Recovery (LMR) Protocol.
- LMR Alternatives:
  - Optimal LMR: Dynamic Programming
  - Heuristic LMR: Uniform Distribution of Redundancy



# Complexity Analysis

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- Time Complexity

- LMMC:  $O(IB_k)$

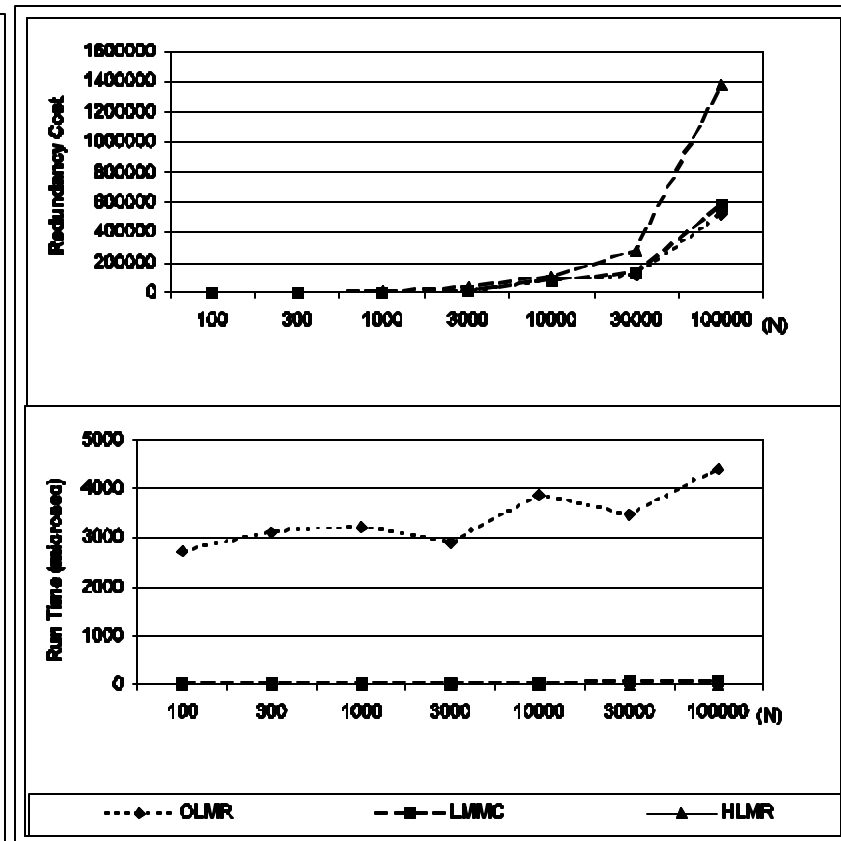
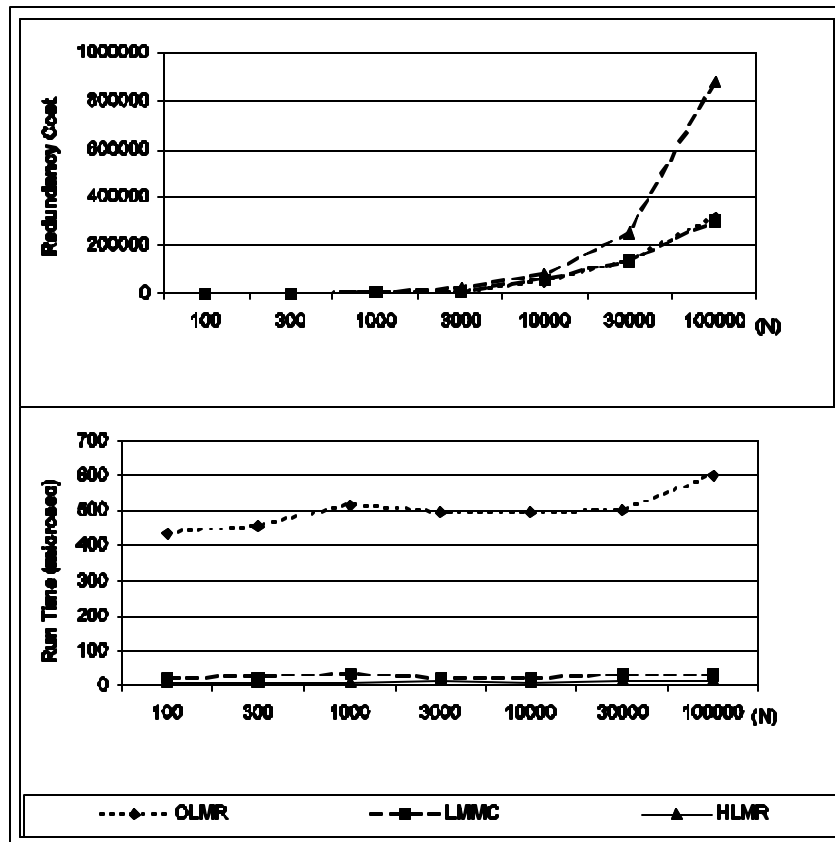
- OLMR:  $O(V_k B_k^2)$

- Space Complexity

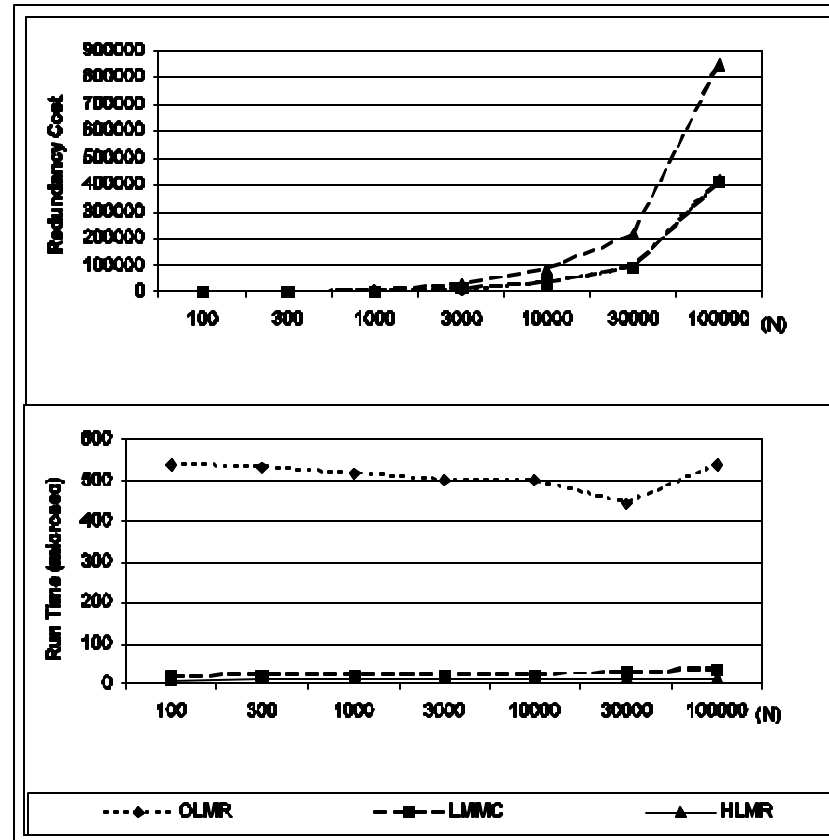
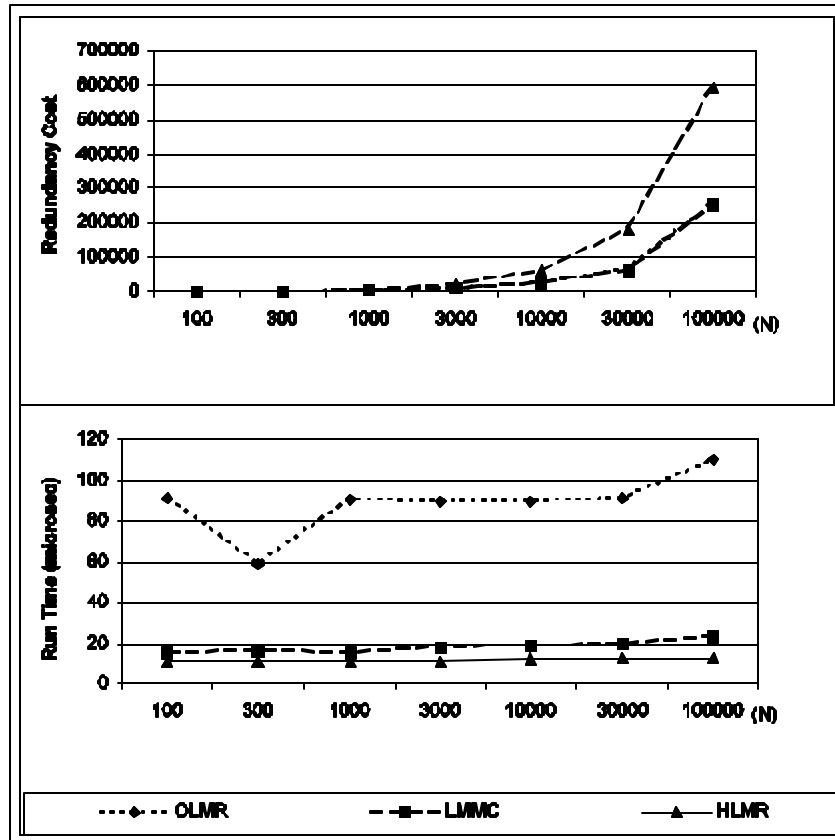
- LMMC:  $O(B_k)$

- OLMR:  $O(B_k^2)$

# Numerical Validation



# Numerical Validation





# References

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