A Multi-Ring Framework for Survivable Group Communications

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http://www.ncassr.org/projects/multicast/

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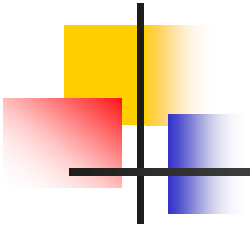


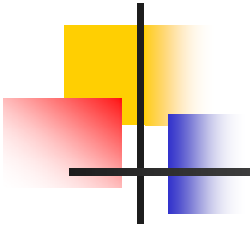
Outline

- Problem Definition
- Background
- Motivation
- Existing approaches:
  - Ring based on Embedded Tree (RET)
  - Ring of Traveling Salesman Tour (RTST)
- Suggested Solution:
  - Multi-ring Virtual Ring (MVR)
- Asymptotic analysis and comparison
- Conclusions and Future Work

Problem Definition

- Goal:
  - Survivable, secure group communication
  - Integrating survivability, security and QoS-guarantees in group communication
    - **Survivability:** Failure tolerance and Reliable message passing.
    - **Security:** Secrecy and source/group message authentication.
    - **QoS:** Soft QoS guarantees (delay, bandwidth…).
    - **Scalability:** Large number of members and/or active sources, Dynamic group membership

- Approach:
  - Application-Level Multicast (ALM) Overlays



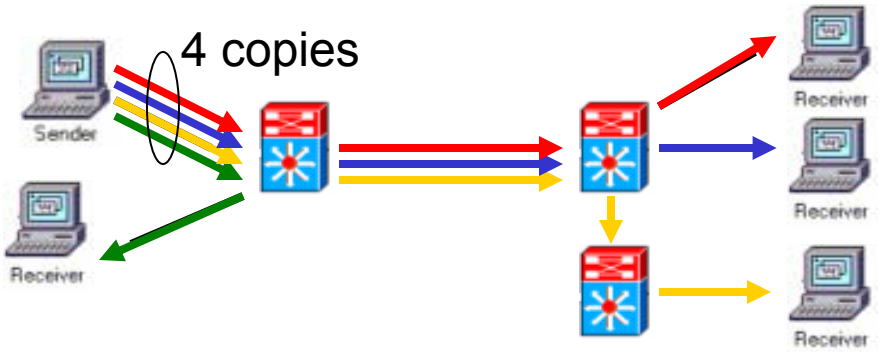
Motivation: Application Perspective

Command and Control System

- Collaborative Editing of Document
  - May include a mission plan (i.e. text, graphical presentation of mission plan, etc)
  - Control and data could be transmitted via a ring overlay
- Distributed Caching
  - Hundreds of mobile units in the field; a subset serve as cache repositories and are responsible for communicating information to the remaining units
  - Information may include:
    - Mission critical plans
    - Updated maps of local terrain (i.e. landmines, enemy bunkers, etc)
  - Group communication is needed for cache updates.

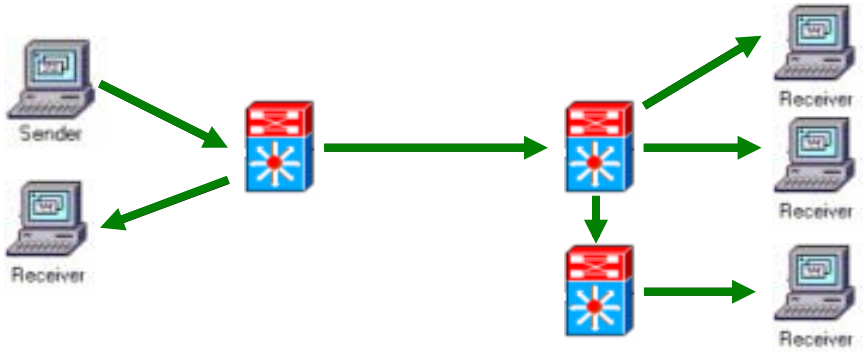
Background: Unicasting vs. IP Multicasting vs. ALM

- Unicasting:



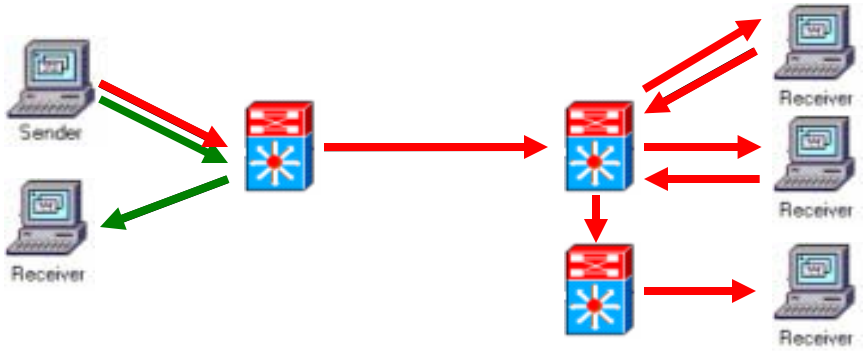
Duplication at sender

- IP Multicasting:

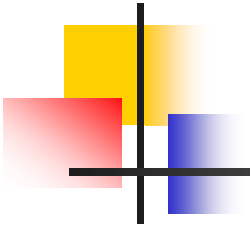


Duplication at routers

- Application-Level Multicasting (ALM):



Duplication at end hosts



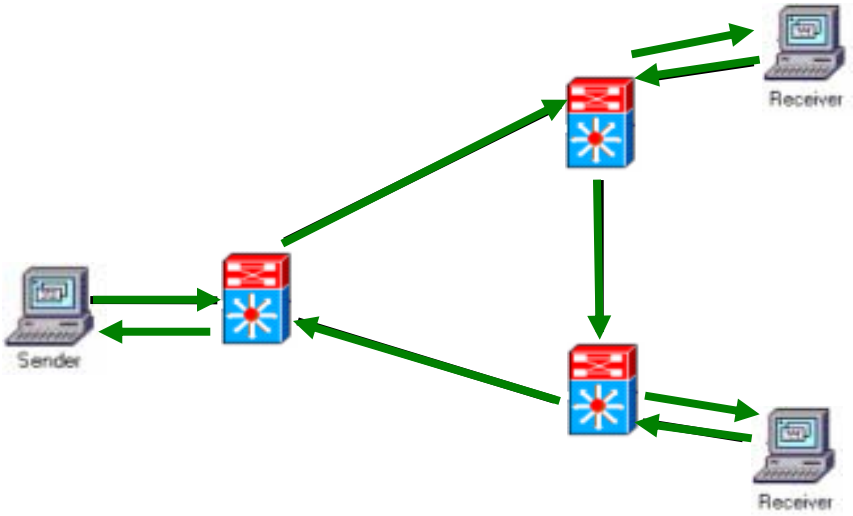
Motivation: Mechanism Perspective

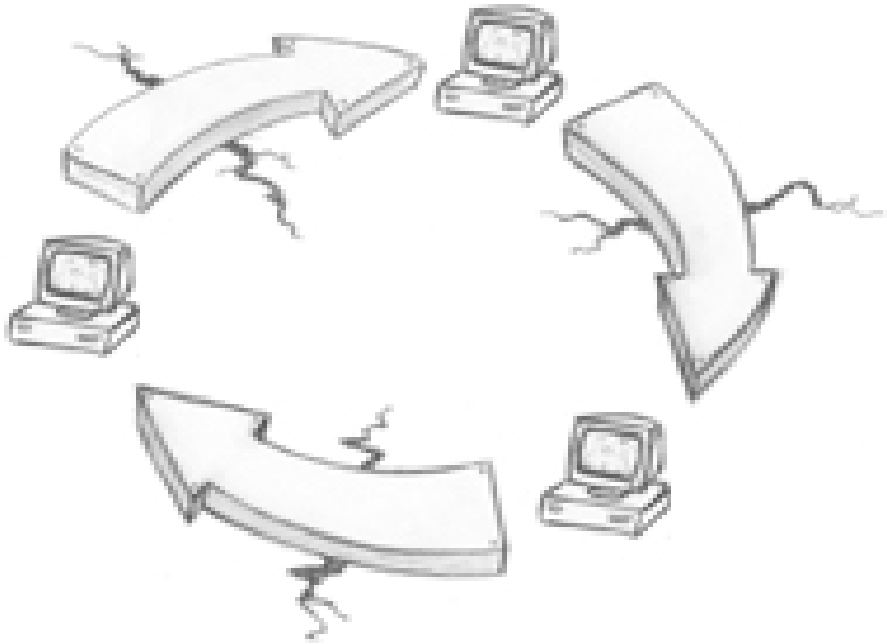
- Current IP multicast schemes (network layer):
  - Complex to implement (not a common-place service)
  - More complex for key mgt (especially with group dynamics)

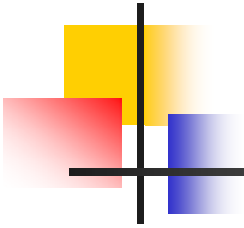
- ALM (application Layer):
  - Use virtual overlay network to simulate multicast
  - Goals :
    - Reduce wasted bandwidth (compared to unicasting)
    - Avoid having to manage an excessive number of connections (compared to unicasting)
    - Higher flexibility and easier management (compared to IP multicasting)

Solution: ALM using Virtual Rings

- Proposed ALM virtual ring overlay solution:
  - O(1) Node degree
  - Inherent reliability and fault tolerance (ACK is not needed)
  - End-system implementation for flexibility
  - Easier key management and easier to deploy multiple key management schemes





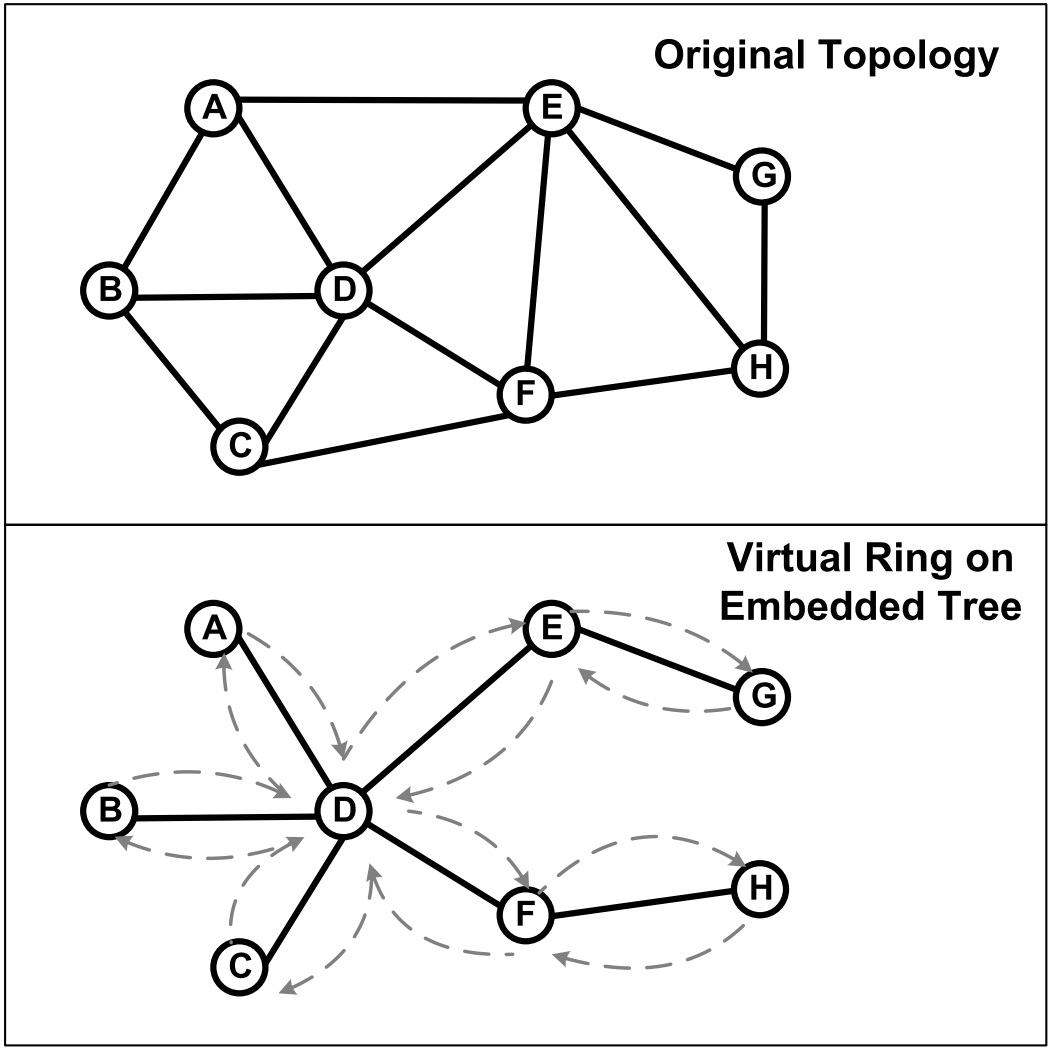


ALM using Virtual Rings: Investigation of Different Approaches

- Existing approaches:
  - Ring based on Embedded Tree (RET)
  - Ring of Traveling Salesman Tour (RTST)
- Our solution:
  - Multi-ring Virtual Ring (MVR) framework

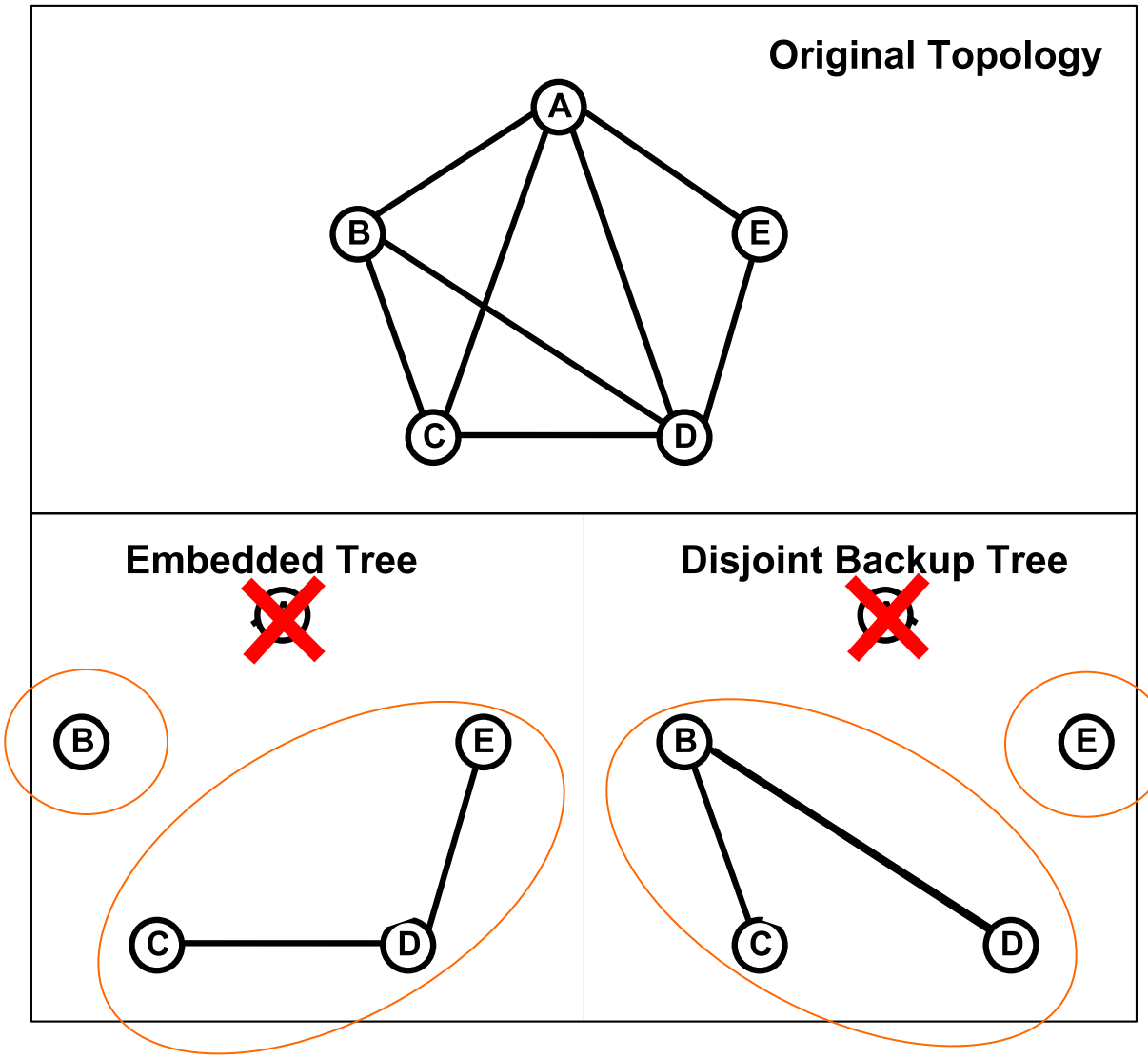
Ring based on Embedded Tree (RET)

- Example:
- Advantage:
  - straightforward and easy to build
- Disadvantages:
  - Can't provide single failure survivability
  - Longer delay



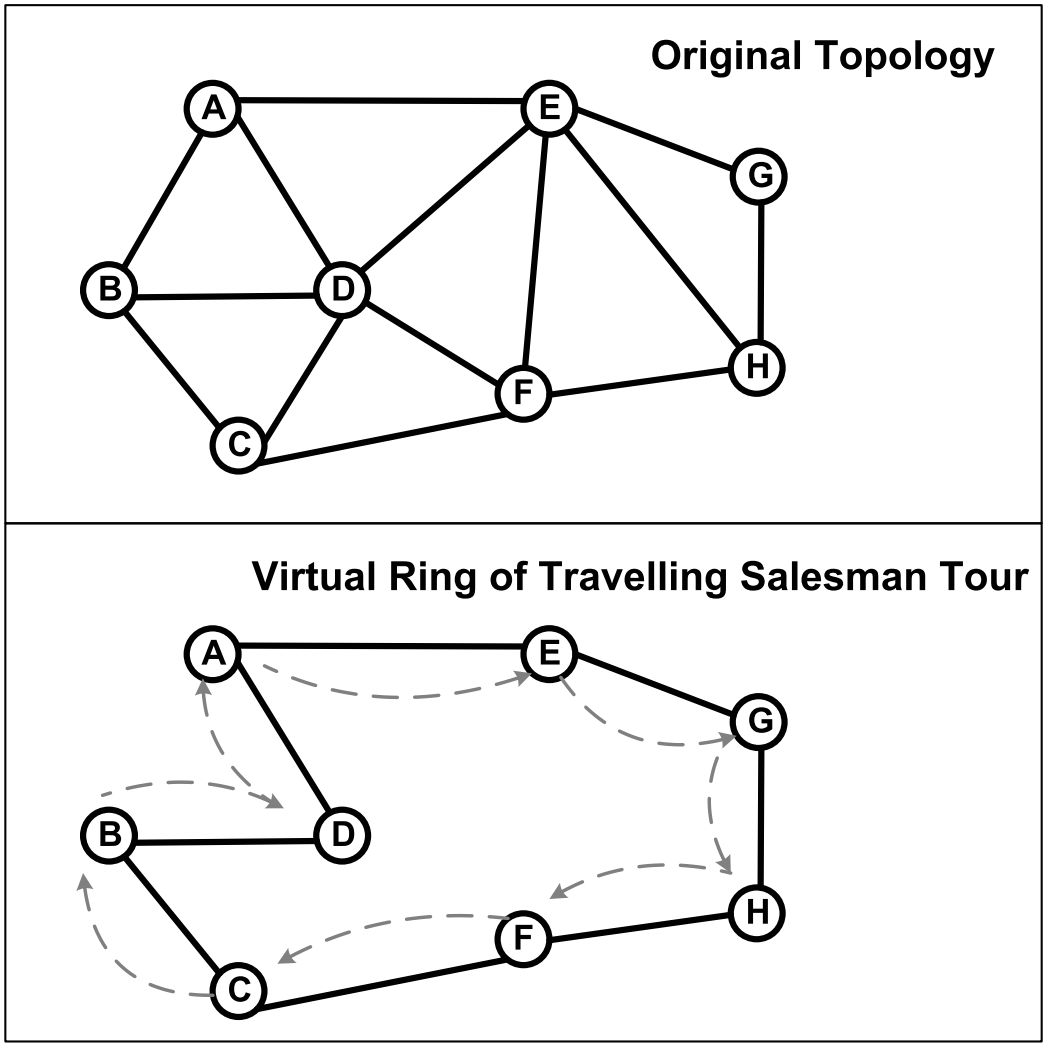
Ring based on Embedded Tree (RET)

- Survivability Analysis:
  - Disjoint backup tree is not sufficient for survivability of RET



Ring of Traveling Salesman Tour (RTST)

- Example:
- Advantage:
  - Optimal w.r.t. cost and e2e delay
  - Inherent single failure survivability
- Disadvantages:
  - Very hard to find: a well-known NP-hard problem

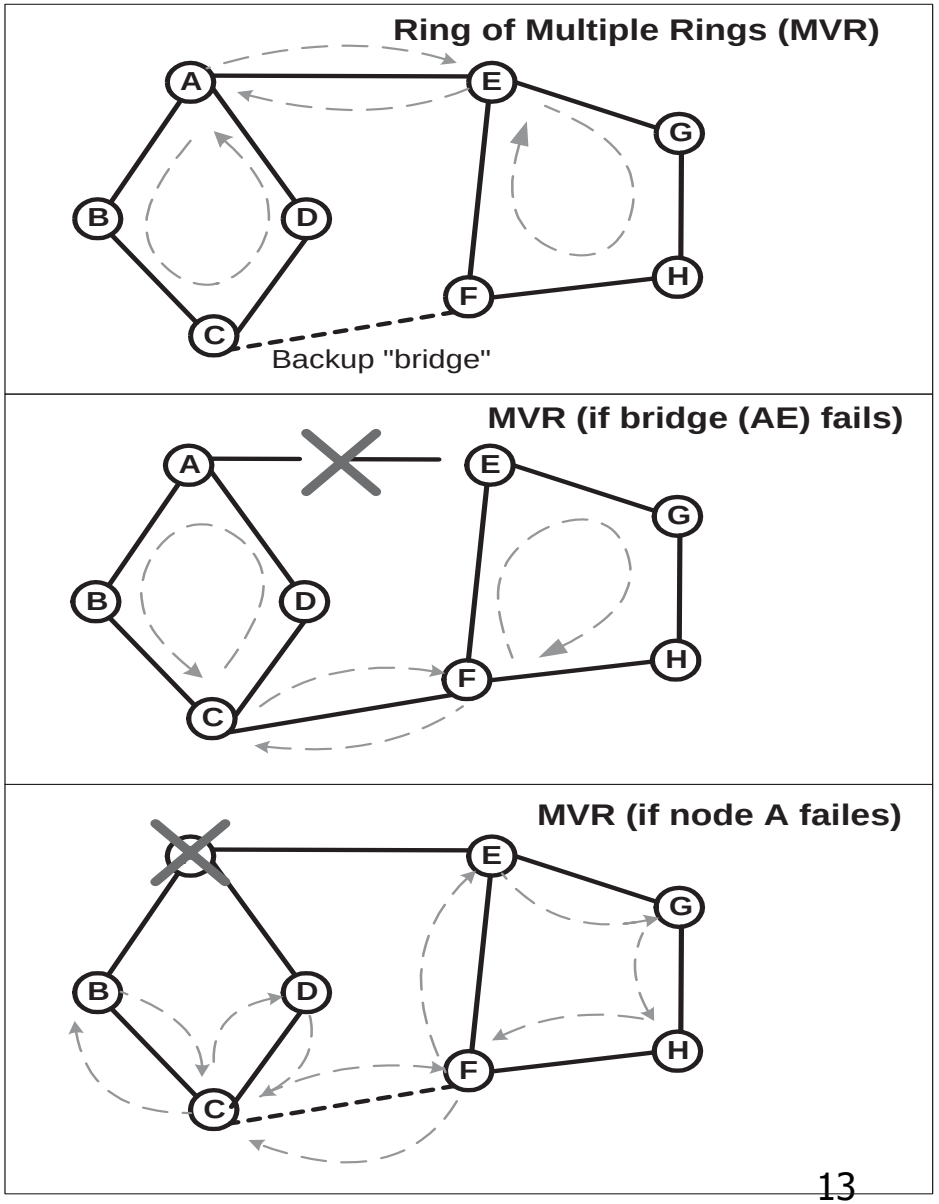


Multi-ring Virtual Ring (MVR)

- Easier to find (compared with the RTST)
- Good for the situation where members are scattered in different domains
- Steps to form MVR:
  - Local search to form local simple rings
  - Find "bridges" to connect these local rings (Dijkstra algorithm may apply)
  - Find "backup bridges" to provide at least single failure survivability

Multi-ring Virtual Ring (MVR)

- Example:
  - Local Rings: <A,B,C,D,A> and <E,G,H,F,E>
  - Bridge: <A,E>
  - Backup bridge: <C,F>
  - MVR: <A,B,C,D,A,E,G,H,F,E,A>
- Survivability:
  - Bridge <A,E> is down: <C,D,A,B,C,F,E,G,H,F,C>
  - Node A is down: <B,C,D,C,F,E,G,H,F,C,B>



Asymptotic Analysis and Comparison

Ring Type	End-to-end Hop-count	Extra Bandwidth
RET	$2(\lvert V_m \rvert - 1)$	$4(\lvert V_m \rvert - 1)b$
RTST	$\lvert V_m \rvert$	$2\lvert V_m \rvert b$
MVR	$\lvert V_m \rvert + 2(k-1)$	$2\lvert V_m \rvert b + 4(k-1)b$

Notations:

- $|V_m|$: total number of members
- b : total amount of bandwidth demand
- k : number of disjoint local rings

Conclusions and Future Work

- Existing IP multicast architecture is not applicable for survivable and secure group communications.
- Application layer virtual rings are proposed as suitable framework.
  - Two existing approaches to build the virtual rings are investigated.
  - Multi-ring Virtual Ring (MVR) is proposed as our solution.
  - Asymptotic analysis and comparison show that MVR is a good candidate.
- Future work:
  - Detailed design and implementation of MVR
  - Simulation and performance evaluation