Dr. Multicast

R_x for Data Center Communication Scalability

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IP Multicast in Data Centers

- IPMC is ***not used*** in data centers

IP Multicast in Data Centers

- Why is IP multicast rarely used?

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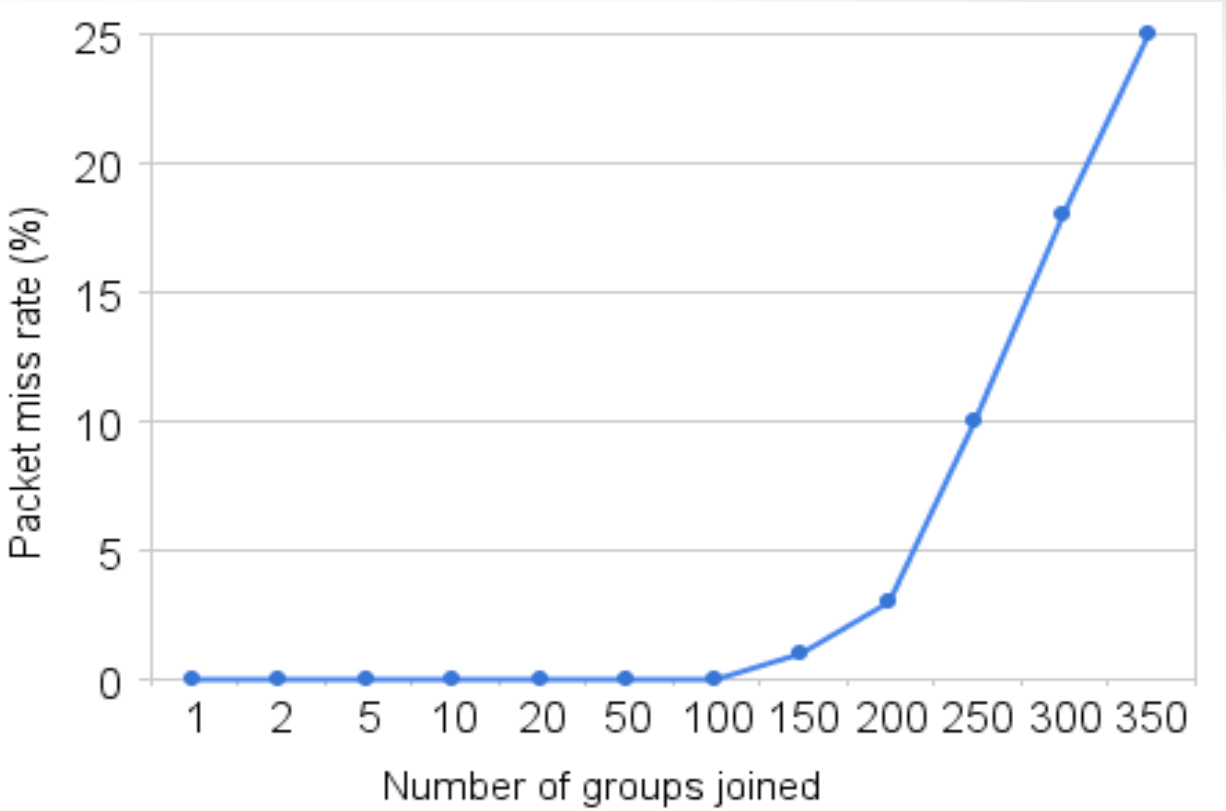
  - Limited IPMC scalability on switches/routers and NICs



IP Multicast in Data Centers

- Why is IP multicast rarely used?
  - Limited IPMC scalability on switches/routers and NICs
  - Broadcast storms: Loss triggers a horde of NACKs, which triggers more loss, etc.
  - Disruptive even to non-IPMC applications.

IP Multicast in Data Centers

- IP multicast has a bad reputation

IP Multicast in Data Centers

- IP multicast has a bad reputation
  - Works great up to a point, after which it breaks catastrophically

IP Multicast in Data Centers

- Bottom line:
  - *Administrators have no control over multicast use ...*
  - Without control, they opt for **never.**

Dr. Multicast

Dr. Multicast (MCMD)

- ***Policy:*** Permits data center operators to selectively enable and control IPMC
- ***Transparency:*** Standard IPMC interface, system calls are overloaded.
- ***Performance:*** Uses IPMC when possible, otherwise point-to-point UDP
- ***Robustness:*** Distributed, fault-tolerant service

Terminology

- ***Process*** : Application that joins logical IPMC groups
- ***Logical IPMC group*** : A virtualized abstraction
- ***Physical IPMC group*** : As usual
- ***UDP multi-send*** : New kernel-level system-call

- ***Collection*** : Set of logical IPMC groups with identical membership

Acceptable Use Policy

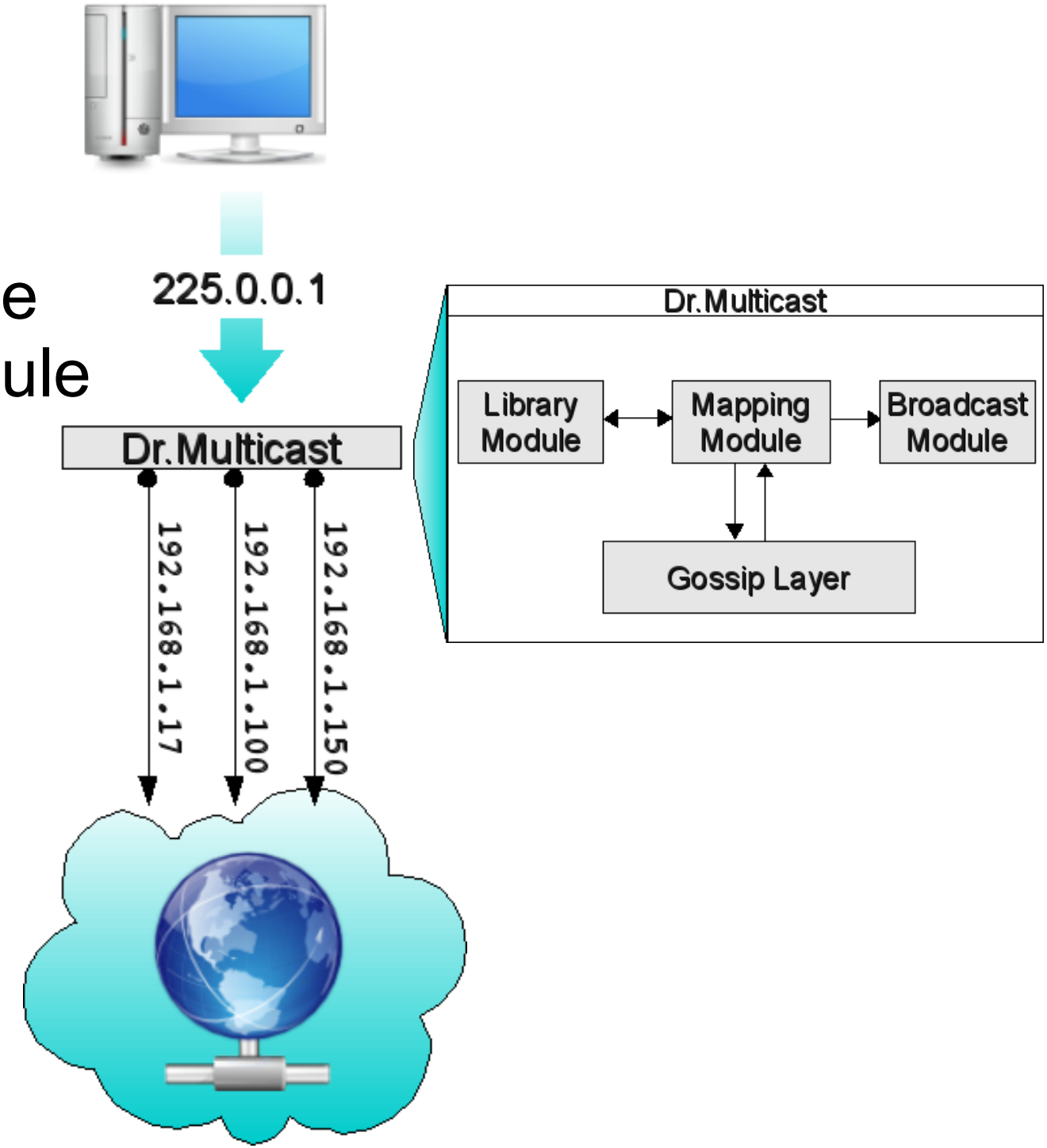
- Assume a higher-level network management tool compiles policy into primitives
- Explicitly allow a process to use IPMC groups
  - ***allow-join(process,logical IPMC)***
  - ***allow-send(process,logical IPMC)***
- UDP multi-send always permitted
- Additional restraints
  - ***max-groups(process,limit)***
  - ***force-udp(process,logical IPMC)***

Overview

- Library module
- Mapping module
- Gossip layer

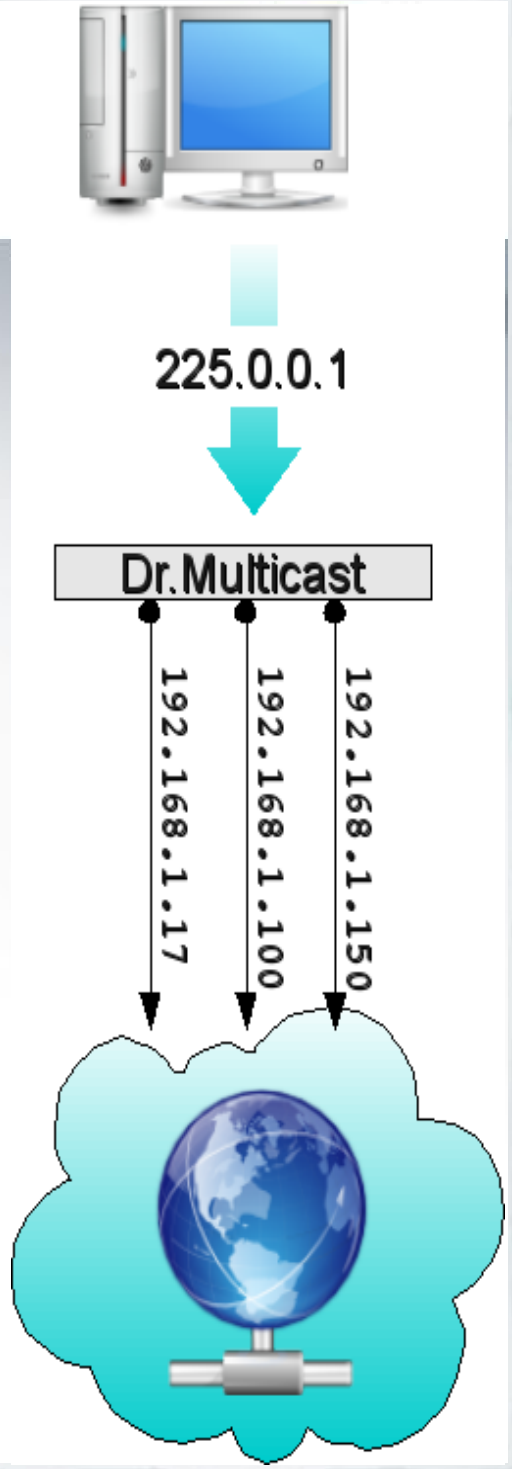
- Optimization questions

- Results



MCMD Library Module

- **Transparent.** Overloads the IPMC functions
  - ***`setsockopt()`*** , ***`send()`*** , etc.
- **Translation.** Logical IPMC map to a set of P-IPMC/unicast addresses.
  - Two extremes



MCMD Mapping Role

- MCMD Agent runs on each machine
  - Contacted by the library modules
  - Provides a mapping
- One agent elected to be a *leader* :
  - Allocates IPMC resources according to the current policy

MCMD Mapping Role

- Allocating IPMC resources: An optimization problem

MCMD Gossip Layer

- Runs system-wide
- Automatic failure detection
- Group membership fully replicated via gossip
  - Node reports its own state
  - *Future:* Replicate more selectively
  - Leader runs optimization algorithm on data and reports the mapping

MCMD Gossip Layer

- But gossip is slow...
- Implications:
  - Slow propagation of group membership
  - Slow propagation of new maps
  - *We assume a low rate of membership churn*
- Remedy: *Broadcast module*
  - Leader broadcasts urgent messages
  - Bounded bandwidth of urgent channel
  - Trade-off between latency and scalability

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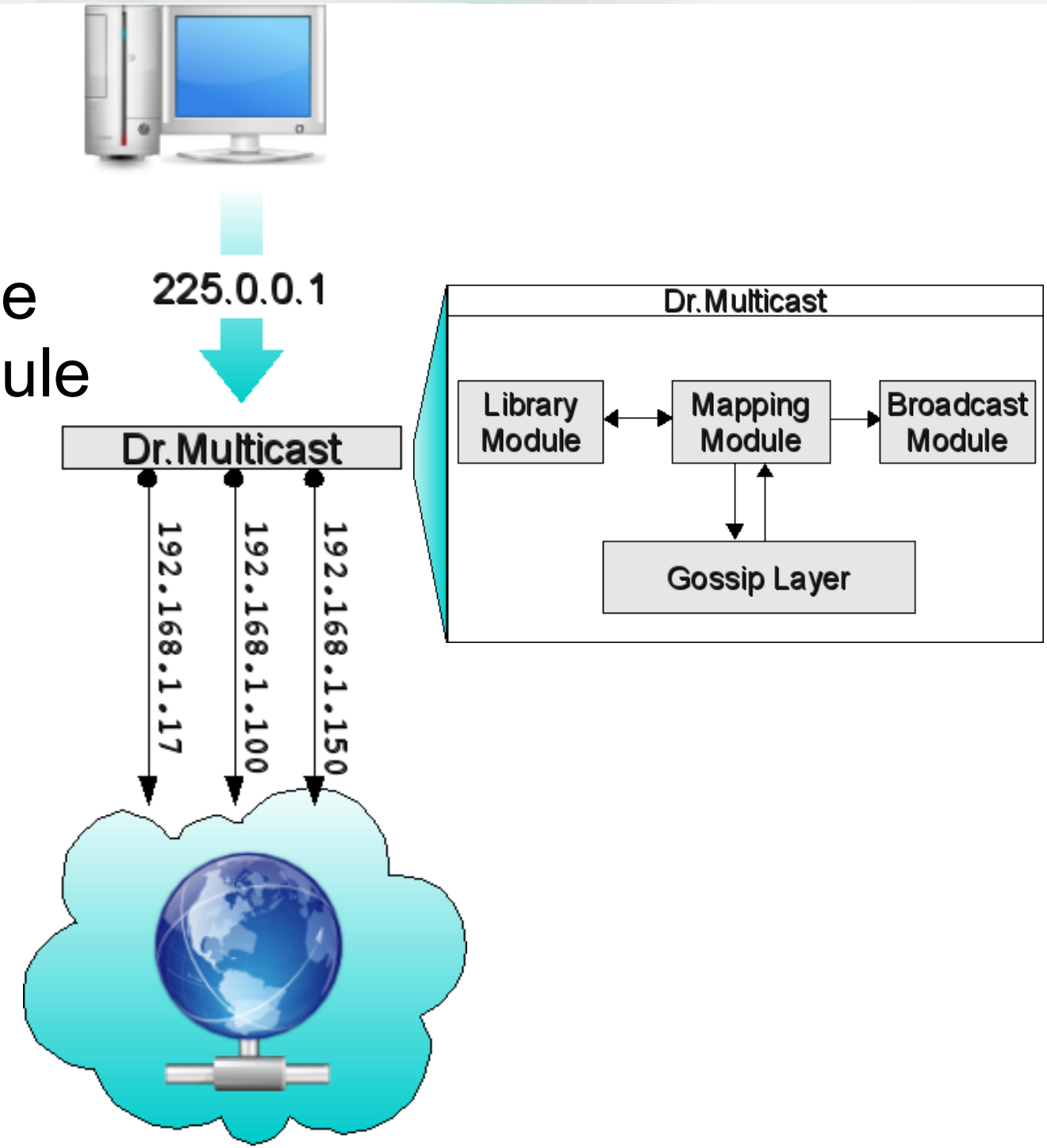
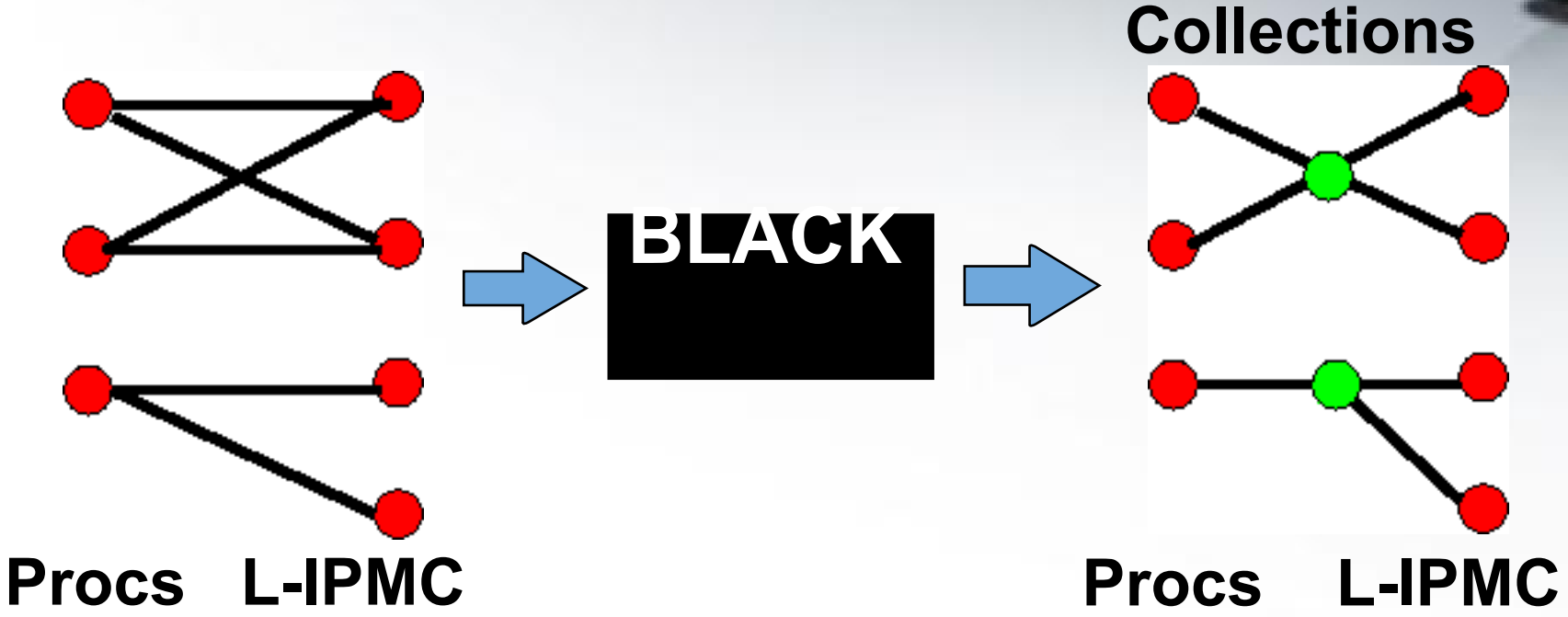


Optimization Questions



- First step: compress logical IPMC groups

Optimization Questions

- How compressible are subscriptions?
  - Multi-objective optimization:
    - Minimize number of collections
    - Minimize bandwidth overhead on network
- Ties in with social preferences
  - How do people's subscriptions overlap?

Optimization Questions

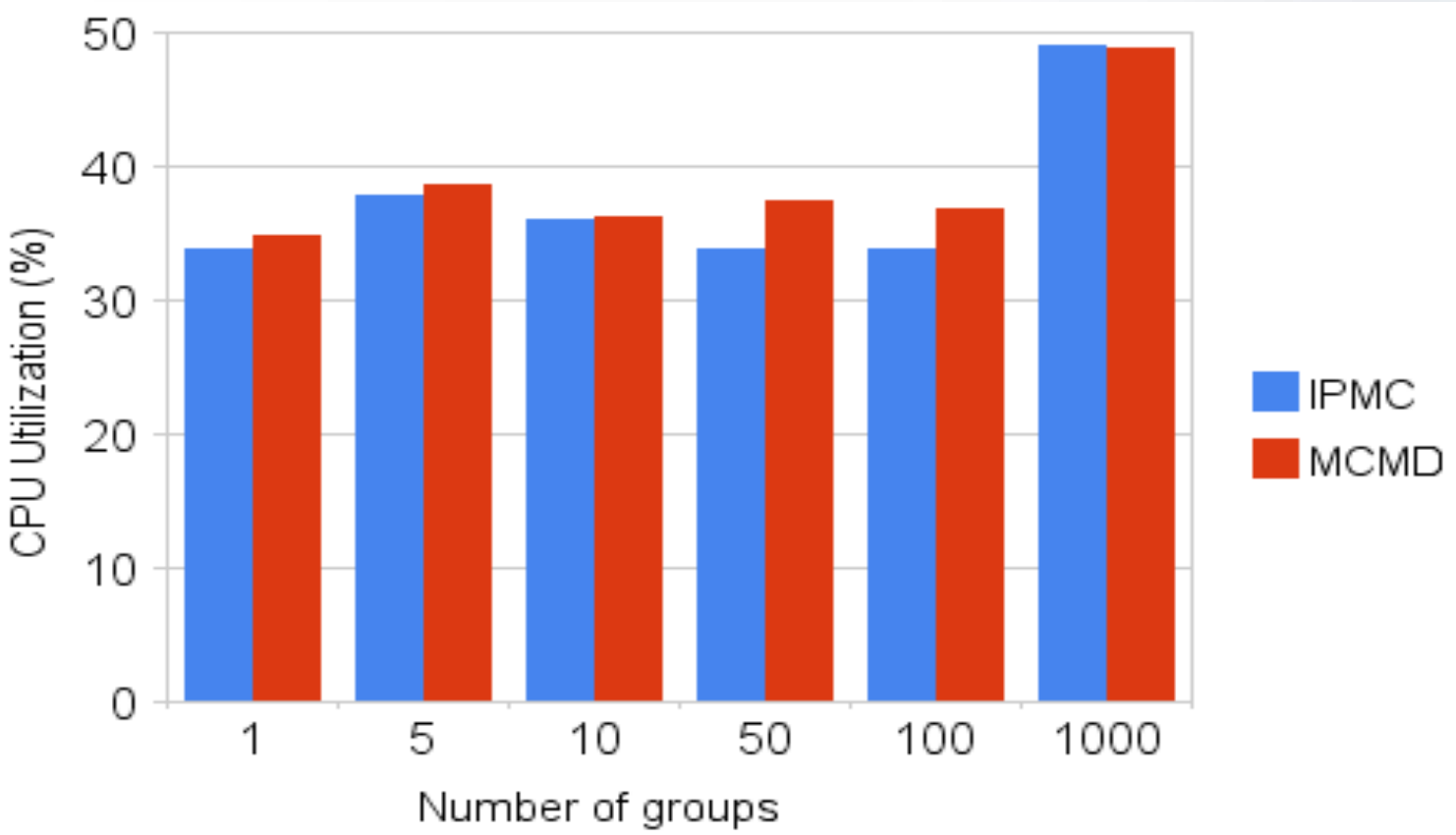
- How compressible are subscriptions?
  - Multi-objective optimization:
    - Minimize number of groups
    - Minimize bandwidth overhead on network
  - *Thm*: The *general* problem is *NP*-complete
  - *Thm*: In uniform random allocation, "little" compression opportunity.
  - Replication (e.g. for load balancing) can generate duplicates (easy case).

Optimization Questions

- Which collections get an IPMC address?
  - *Thm:* Ordered by decreasing *traffic*size* , assign P-IPMC addresses greedily, we minimize bandwidth.
- *Tiling* heuristic:
  - Sort L-IPMC by *traffic*size*
  - Greedily collapse identical groups
  - Assign IPMC to collections in reverse order of *traffic*size* , UDP-multisend to the rest
- Building tilings incrementally

Overhead

- Insignificant overhead when mapping L-IPMC to P-IPMC.

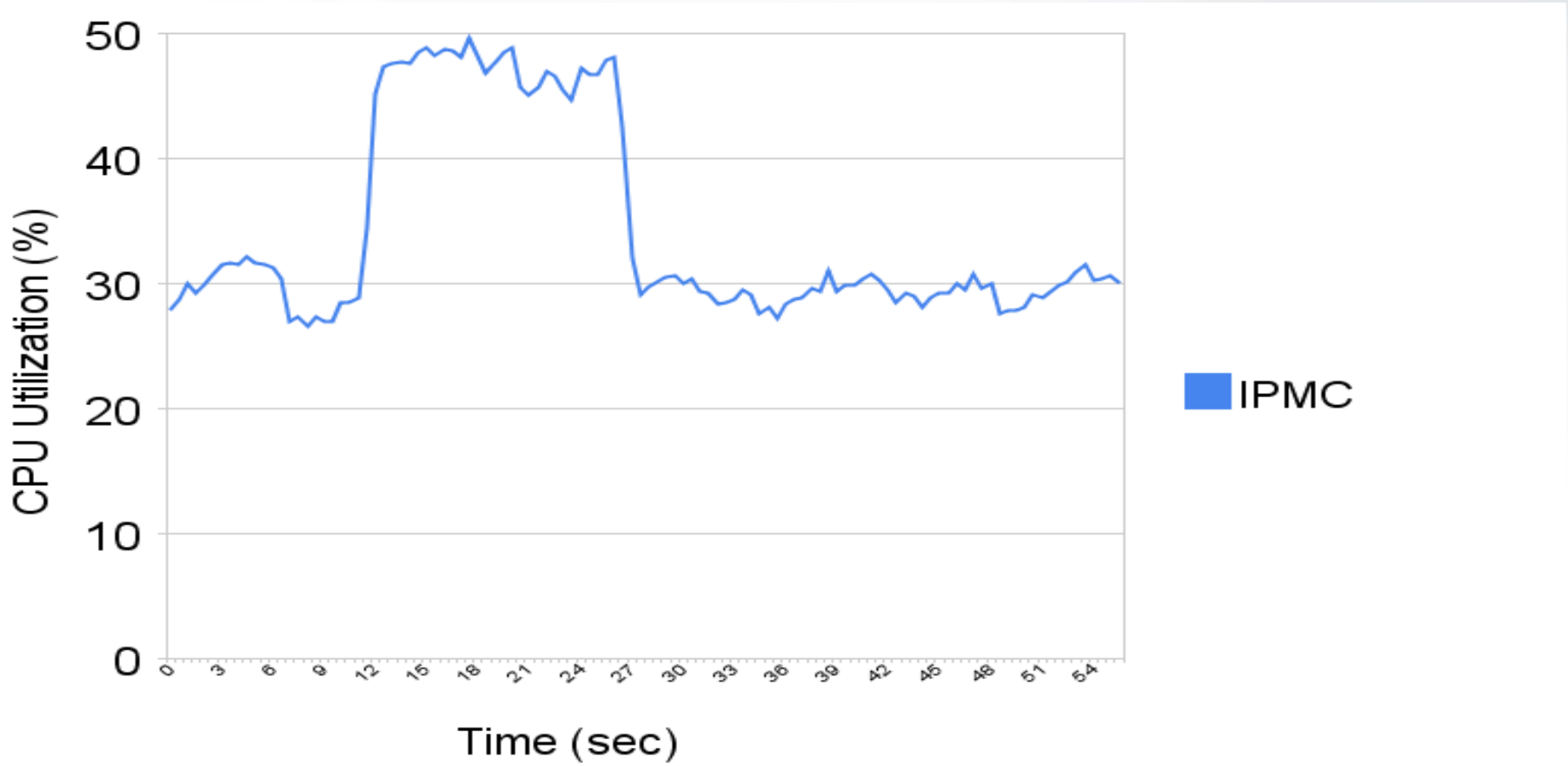


Overhead

- Linux kernel module increases UDP-multisend throughput by *17%* (compared to user-space UDP-multisend)

Policy control

- A malfunctioning node bombards an existing IPMC group.
- MCMD policy prevents ill-effects



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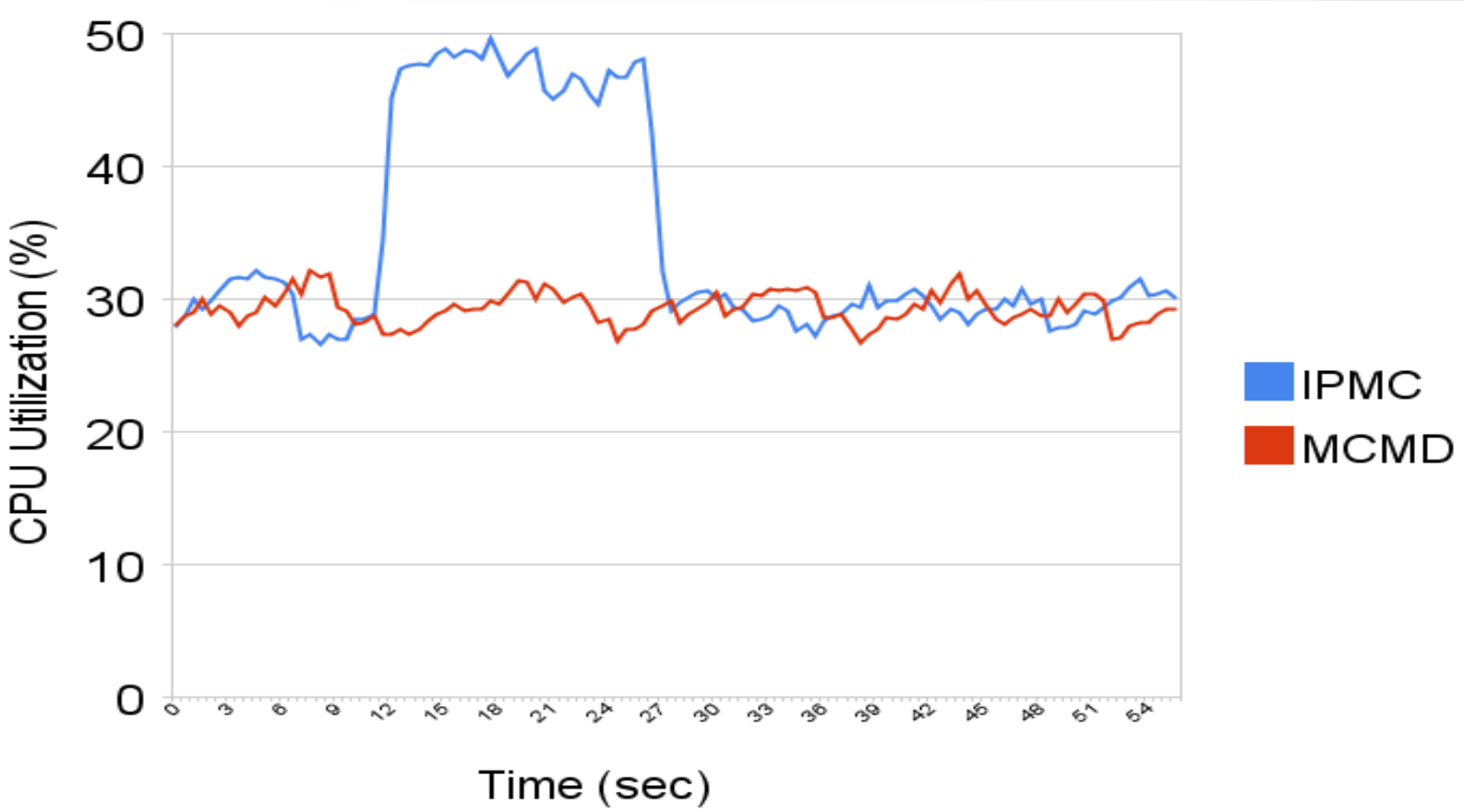

Network Overhead

- MCMD Gossip Layer uses constant background bandwidth

- Latency of leaves/joins/new tilings bounded by gossip dissemination latency

Conclusion

- IPMC has been a bad citizen...

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- IPMC has been a bad citizen...
- *Dr. Multicast* has the cure!
- Opportunity for big performance enhancements and policy control.