Dealing with Heterogeneity in a Fully Reliable Multicast Protocol

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Introduction

Heterogeneity in Multicast

- A multicast session involves many receivers which can have different capacities.
- To accommodate receivers' heterogeneity:
  - **Single-rate multicast**: the transmission rate is adapted in response to the most congested receiver.
  - **Multi-rate multicast**: the source transmits with multiple different rates.
- Multi-rate multicast improves receivers' satisfaction

Multi-rate Multicast

Layered Multi-rate Multicast RLM [Jacobson96], RLC [Vicisano98], FLID-DL [Byers00]

- Data is encoded into a number of layers that can be incrementally combined.
- Every layer is sent on a separate multicast address.
- Receivers join and leave groups depending on their needs

Replicated Multi-rate Multicast DSG [Jiang00]

- The source transmits multiple copies of the same data at different rates
- A receiver needs to subscribe to only one group

A Receiver-based Replicated Scheme

A Receiver-based Replicated Scheme

- Data replication is performed by some designated receivers “replicators” instead of the source.
- These replicators are designated through the execution of a partitioning algorithm where the receivers are split into subgroups of similar capacities.
- A receiver from a fast subgroup is chosen as the replicator for a subgroup of a slower capacity.
- In this way, a *regulation tree* is built with the source as the root and the replicators as intermediate nodes.

A Receiver-based Replicated Scheme

- The partitioning algorithm can be executed at the source or at the routers.
- Performing the partitioning by the routers:
  - allows for more scalability even with a small number of subgroups.
  - allows for the construction of a regulation tree which is close to the multicast distribution tree.

Regulation Tree Construction

[Maimour:HSNMC03]

Require: $N > 1$ and $a < b$

$P_0 \leftarrow \{l_j, j = 1, \ldots, N\}$, the set of all the links downstream.

Periodically,

- **if** $\exists j, l_j \in P_0$ such that $\Delta\dot{\tau}_j > b$ **then**
  - $P_i \leftarrow \{l_j \in P_0, \Delta\dot{\tau}_j > a\}$ and $P_0 \leftarrow P_0 - P_i$
  - $Rep_i \leftarrow Best(P_0)$
  - **if** $i > 1$ **then**
    - $Rep_{i-1} \leftarrow Best(P_i)$
  - **end if**
  - $i \leftarrow i + 1$
- **end if**

until no split is possible

Examples

Multicast Session Utility

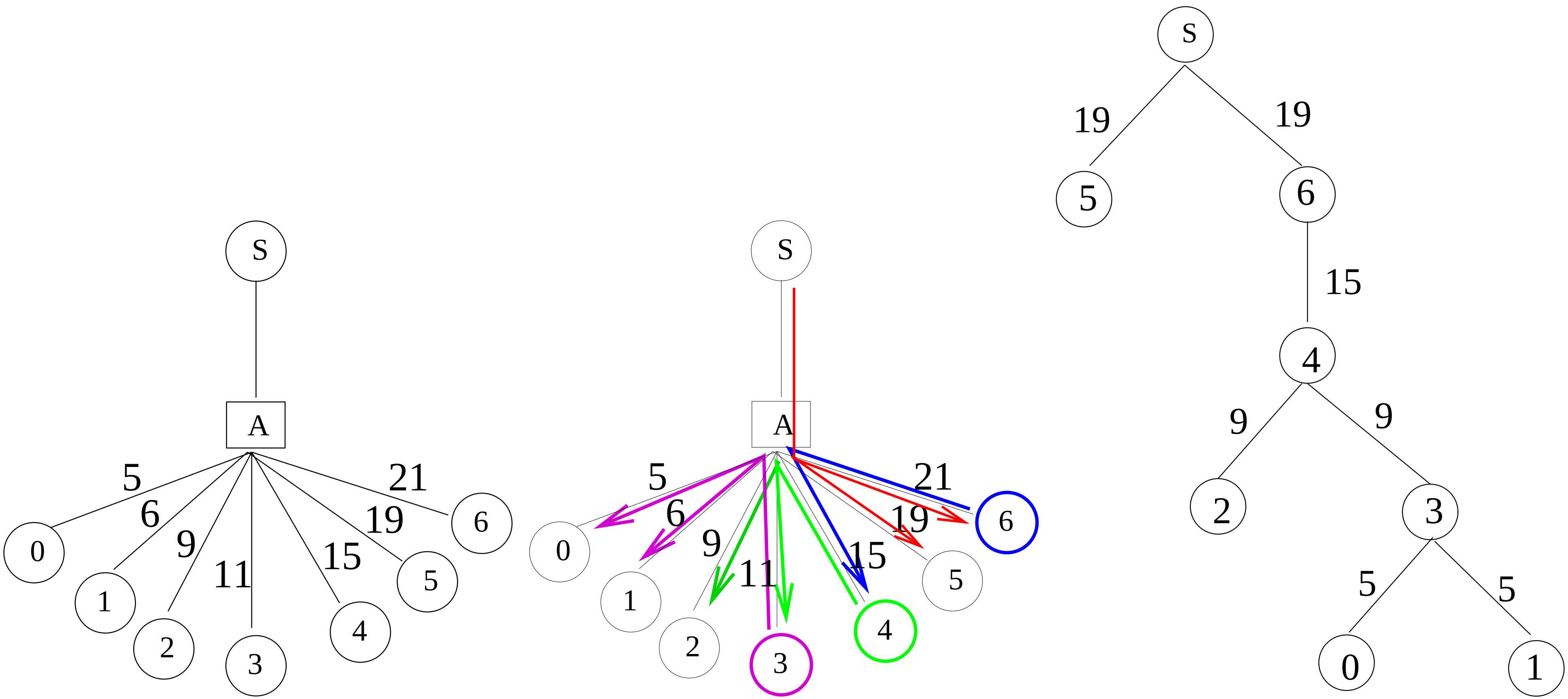
- For receiver R_i : $U_i(r) = \frac{\min(r_i, r)}{\max(r_i, r)}$ [Jiang98]
- **A Multi-rate Multicast Session Utility**

$\{R_1, R_2, \ldots, R_N\}$ is split into K subgroups $\{G_1, G_2, \ldots, G_K\}$ with transmission rates $g_1, g_2, \ldots, g_K$, then

$$U(g_1, g_2, \ldots, g_K) = \sum_{j=1}^{K} \sum_{i=1}^{n_j} \alpha_{i,j} U_{i,j}(g_j)$$

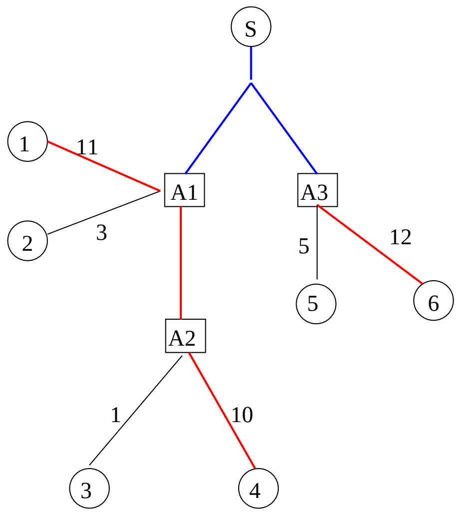
subject to $\sum_{i,j} \alpha_{i,j} = 1$ where $\alpha_{i,j} \in [0, 1]$
$\sum_j n_j = N$ where n_j is the number of the receivers in subgroup G_j.
$U_{i,j}(g_j)$ and $\alpha_{i,j}$ are respectively the utility function and the weight associated to the ith receiver of the jth subgroup.

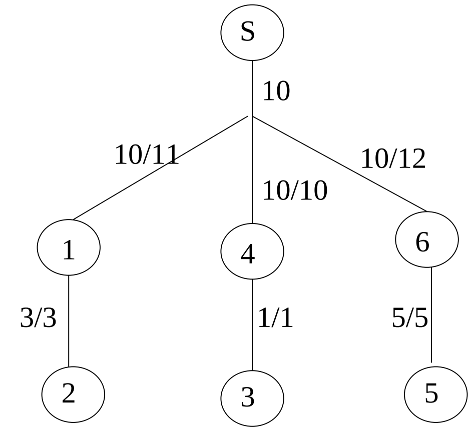
A Simple Example



$P_0 = \{5, 6\}$, $P_1 = \{0, 1\}$, $P_2 = \{2, 3\}$, $P_3 = \{4\}$
$U = 0.936$ instead of 0.525

A Hierarchy of Routers



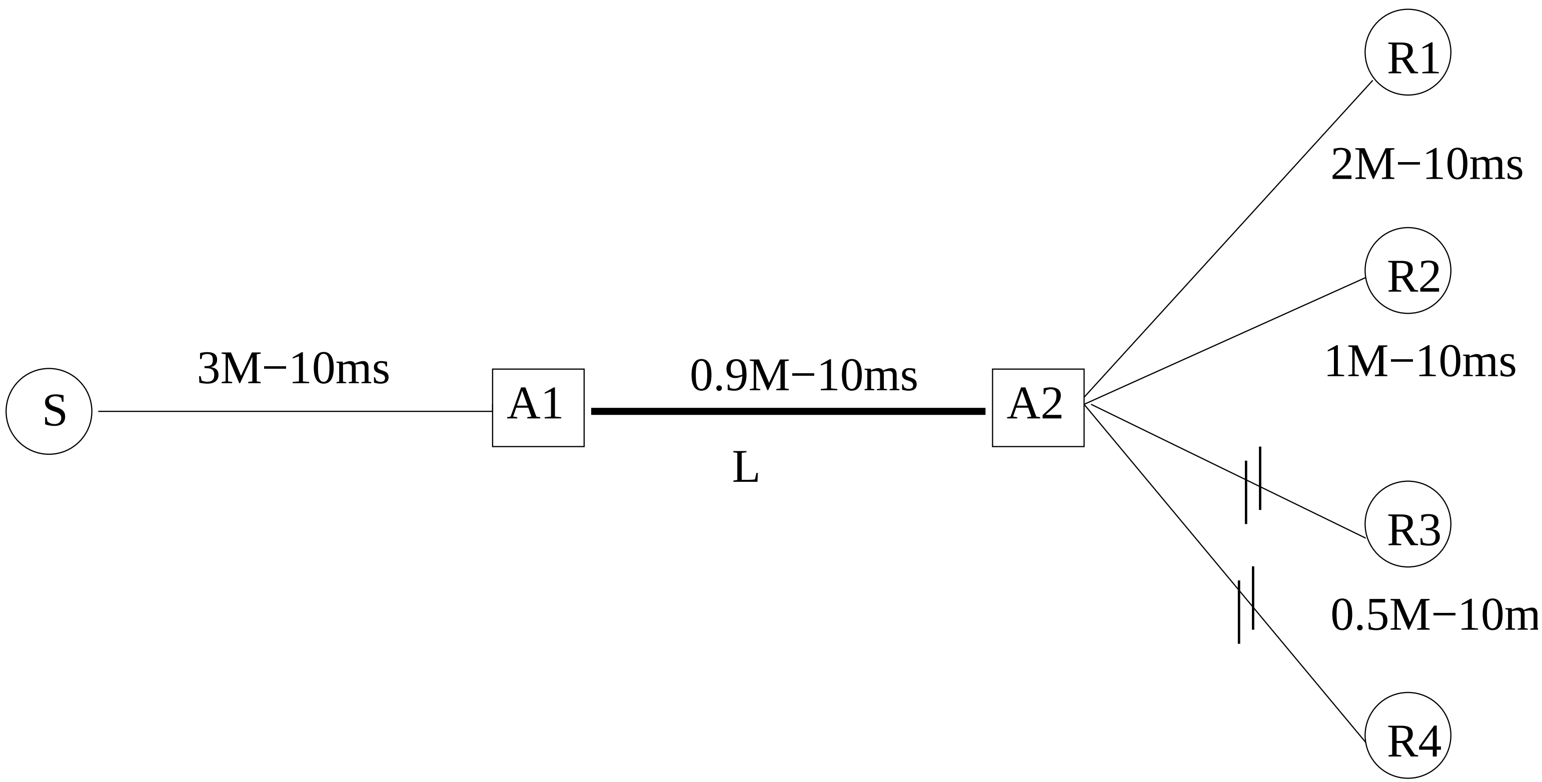


$$P_{0,1} = \{R_1, A2\},\ P_{1,1} = \{R_2\}$$
$$P_{0,2} = \{R_4\},\ P_{1,2} = \{R_3\} \quad \Rightarrow \quad P_0 = \{R_1, R_4, R_6\}, P_1 = \{R_2\}$$
$$P_{0,3} = \{R_6\},\ P_{1,3} = \{R_5\} \qquad P_2 = \{R_3\}, P_3 = \{R_5\}$$

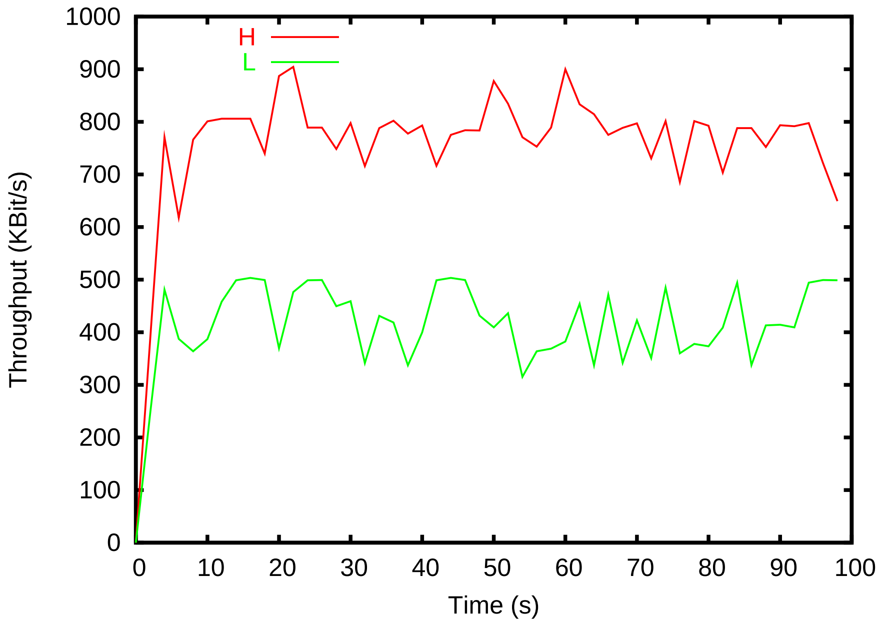
$U_a = 0.957$ instead of 0.301 and $rate_S = 10$ instead of 1.

Simulation Results

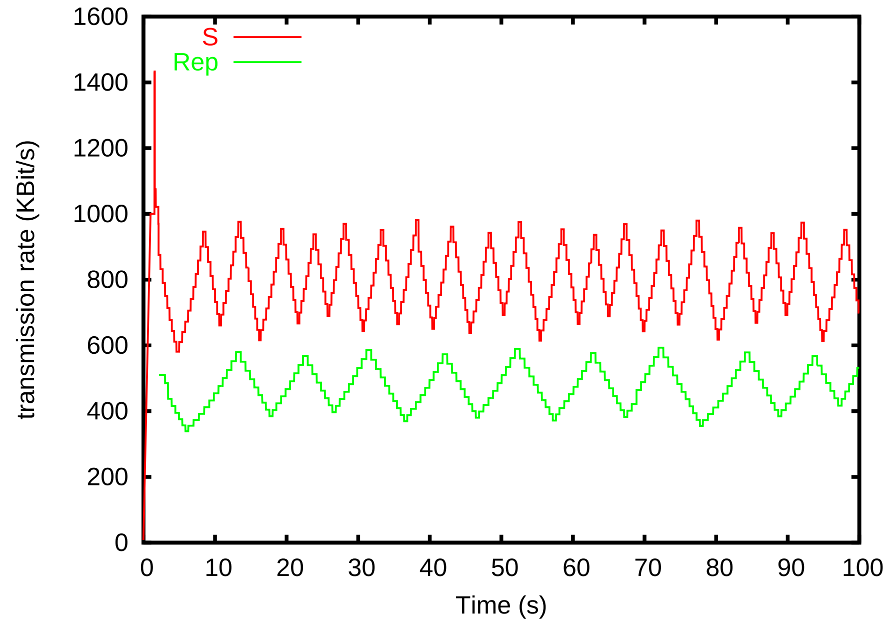
- ns simulator
- AMCA [Maimour:ISCC03] : Active-based Multicast Congestion Avoidance Algorithm.



Simulation Results (cont.)



(a)



(b)

(a) The throughput achieved by the two subgroups with $r_1 = r_2 = 0.9$Mbps and $r_3 = r_4 = 0.5$Mbps.

(b) Transmission rate of the source and the replicator.

Conclusion

- In order to accommodate heterogeneity, a receiver-based replicated scheme is proposed:
  - the replication burden is distributed among some receivers instead of overloading the source.
  - local subgroups are formed allowing for more scalability.
  - the regulation tree built is close to the multicast tree.
- The partitioning algorithm:
  - is simple, does not require a prior knowledge of the receivers' capacities,
  - performs an on-the-fly partitioning as soon as it receives feedback from the receivers.

Future Work

- Simulations have to be performed on more complex topologies.
- Dynamic behavior Evaluation of our approach where the receivers may change their capacities over time.