An analysis of the paper

"Efficient Multimedia Distribution in Source Constraint Networks" [1]

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Abstract

This paper provides an analysis of the paper "Efficient Multimedia Distribution in Source Constraint Networks" [1] and the related subject matter. The goal of the paper "Efficient Multimedia Distribution in Source Constraint Networks" is to optimize the efficiency of data dissemination in a P2P (Peer to Peer) source constrained network. Based on this overall goal, the paper seeks to provide the following:

1. **Improved throughput efficiency.** An improved quantitative data dissemination solution is sought that is applicable to any source constrained network.
2. An **optimal [network] topology** is sought that is a network topology suitable for data dissemination in P2P networks, *whereas an ideal topology is said to be one that allows all peers to contribute their full bandwidth.*
3. An **optimal system architecture** within a P2P system is sought based on the proposed optimal network topologies.

This paper provides a detailed analysis of "Efficient Multimedia Distribution in Source Constraint Networks" in the following sections:

1. **The Problems to be Solved**
2. **The Proposed Solutions**
3. **Strengths of the Proposed Solutions / Effectiveness**
4. **Weaknesses of the Proposed Solutions / Additional Considerations**
5. **Conclusion**

Overall, "Efficient Multimedia Distribution in Source Constraint Networks" *("the paper" henceforth)* proves effective based on solid simulation and testbed results utilizing PlanetLab [2].

1. The Problems to be Solved

"Efficient Multimedia Distribution in Source Constraint Networks" provides an analysis of the *problems* confronting source contained P2P networks. From this, the paper seeks to optimize the following challenges confronting source constrained P2P Networks:

1. **Optimal average useful throughput:** Bandwidth usage of all the nodes is optimal in the sense of average useful throughput.
2. **Minimize end-to-end delay:** End-to-end delay from the source to any node is sought to be minimized in order to support real-time applications.
3. **Node flexibility:** Nodes can join and leave without causing much disruption to other nodes. The complexity of a node's leaving and joining is related to the out-degree of the node. For example, if a node connects to many neighbors, its leaving will affect many nodes.
4. **Equal distributed bandwidth:** Bandwidth is fairly distributed among nodes, i.e., the total receiving and sending rates of a node are equal to each other.

2. The Proposed Solutions

"Efficient Multimedia Distribution in Source Constraint Networks" is laid out consistent to the goals noted above (*see* Abstract above). Further, for each goal, the paper identifies solutions as follows:

A. Improved Throughput Efficiency. The paper seeks to optimize throughput efficiency as defined as "E", as follows:

$$E = \frac{\text{Total useful sending rate of all nodes}}{\min(\text{total max. sending rate of all nodes, max. receiving rate of all nodes from the source})}$$

Whereas an optimal efficiency E = 1 is sought.

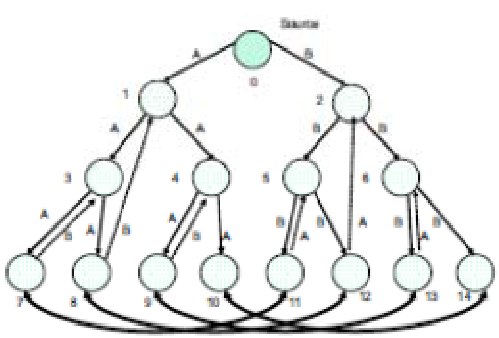
To this end, the paper analyzes a number of topologies and identifies that each topology presented offers E=1, yet with varying latencies as discussed below.

B. Optimal Topologies. The paper identifies a number of topologies and their associated latencies as follows:

Topology	Maximum Latency
Balanced Mesh	$\log_b((b - 1)N + b) + 1$
Cascaded Mesh	$O((\log_b N)^2)$; *see* footnote 1.
b-Unbalanced Mesh	$[\log_b(N + 1)] + 3b - 4$

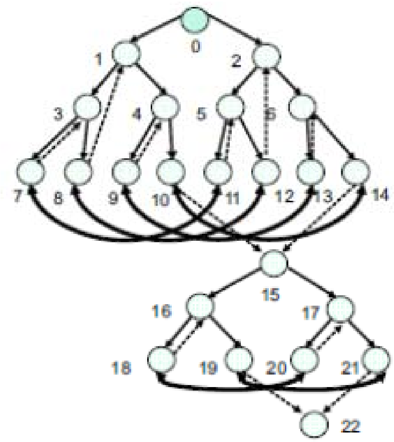
Where b = the out-degree and N = the number of nodes. Each of these topologies are further described below:

Balanced Mesh. The Balanced Mesh topology simultaneously optimizes both the delay and out-degree ("b", being the number of outbound data connections emanating from the node). As an example, for an out-degree of two (2), the topology offer pairs of leaves at the bottom of the mesh as shown in Fig. 2 of the paper. As shown, the leaves provide outputs back to other leaf nodes, parent nodes, or grandparent nodes in a repeatable pattern based on the out-degree (noting that the out-degree of the right-most leaf is b-1).



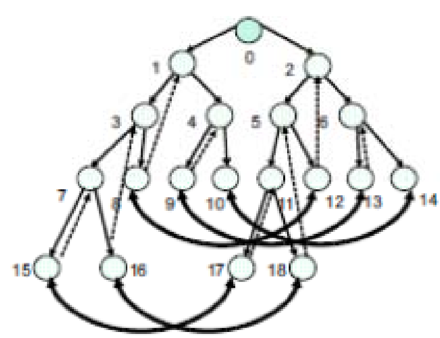
(Balanced Mesh, *id.* at Fig. 2 (a))

Cascaded Balanced Mesh. A Cascaded Balanced Mesh (shown below) is simply a cascaded series of two or more of the above shown Balanced Mesh networks. *The significant disadvantage of a Cascaded Balanced Mesh is the fact that the latency in such a network is the result of the series of Cascaded Balanced Mesh networks,* versus the latency of simply a single Balanced Mesh.



(Cascaded Balance Mesh, *id.* at Fig. 2 (b))

b-Unbalanced Mesh. Based on the foregoing discussions about the Balanced Mesh and the Cascaded Balance Mesh, *the b-Unbalanced Mesh (shown below) provides optimal latency as compared to the Cascaded Balance Mesh by limiting the size, thus the depth (and latency) of the secondary mesh*. In the b-Unbalanced Mesh topology, this is done by limiting the size of the secondary mesh to b^2-1. To expand, when a secondary mesh reaches b^2, the mesh is "destroyed" and "rebuilt" by redistributing the secondary mesh nodes to the ends of the primary mesh leaves as is shown below and further described in the paper's algorithm for "rebuilding, a b-unbalanced mesh when a node joins" (*see id.* at pg. 5).



(b-Unbalanced Mesh, *id.* at Fig. 3 (d))

From the above, it is found that optimal latency is realized in the Balanced Mesh, however, when nodes join and the mesh expands (while

[1] Whereas for a mesh with depth O(i), the total delay of the entire balance mesh is $O(i^2)$ where $i=(\log_b N)^2$.

assuming a constant out-degree), then the b-Unbalanced Mesh provides superior latency as compared to the Cascaded Balanced Mesh.

C. Optimal System Architecture. The paper proposes a "Hybrid P2P System Architecture" based on the abovementioned b-Unbalanced Mesh because of the optimal latency as discussed above. Further, the paper teaches the addition of a "Super Node" with the following attributes:

Super Node Attributes (*see id.* at pg. 6)
The super node functions as the system controller to instruct other peer nodes.
Peers nodes obtain information on neighboring nodes from the super node.
The super node monitors the heart beat of all other nodes.
The super node provides a soft handover between peer nodes when new nodes are added or deleted from the system.

D. Summary: *Thus in summary,* the proposed solution is a system that provides:

1. *Improved throughput efficiency* (E) equal to 1.
2. *An optimized latency* b-Unbalanced Mesh topology.
3. *An overall optimized system architecture* that utilizes a "Super Node" which provides the above mentioned attributes.

I find each of these aspects of the system solution presented by the paper are important for the reasons indicated in italics above and further discussed below.

3. Strengths of the Proposed Solutions

Both testing and simulation proves that the paper's proposed solution set is effective in the three key areas: (1) improved throughput efficiency, (2) optimized latency, and (3) optimized system architecture. The proven strengths and favorable results are summarized as follows:

A. **Improved Throughput Efficiency:** System throughput was tested on a small scale deployment using PlanetLab [2], using TCP. The results indicate superior performance over multicast, especially as the out-degree increases.

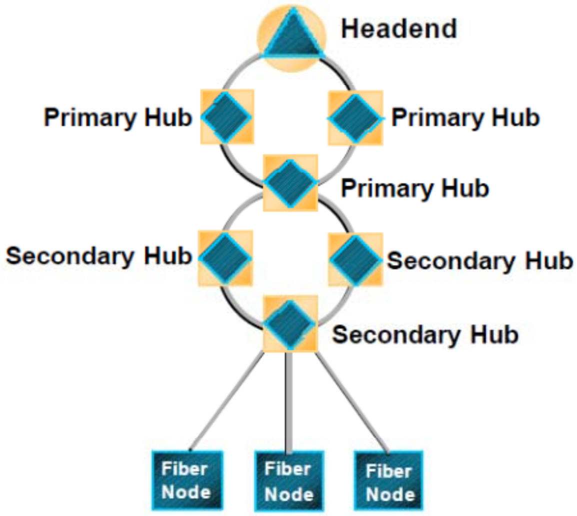
B**. Optimal Topology.** In addition to testing throughput, *additional small scale testing* was performed including but limited to testing: (1) the arrangement of peers within the mesh, including (2) the impact due to varying the out-degree, (3) the impact of a node leaving the mesh, (4) the impact of optimizing the peers in a mesh and join time. Overall, relative to an increase in the out-degree, the impact of a peer leaving / joining increased, while download / upload speed stayed relatively constant, and the overhead data from the super node increased. All of these results are considered to be within acceptable limits.

Further, large scale simulation was performed over a spectrum of scenarios including: simulating the impact of out-degree on throughput for the proposed solution as compared to multicast, (2) simulating the impact of capacity variation, (3) simulating node failure impacts, and simulating failure intervals. In brief, results performed as expected, far surpassing the performance of multicasting.

C. Optimal Architecture. While no testing appears to have been done explicitly to the impact of the presence / absence of the super node architecture versus an architecture without a super node, a number of advantages are noted:

Super Node Advantages
Centralized security and authentication.
Centralized upgrade source.

D. Summary. The above listed performance factors are all important and comprehensive. To expand, these factors are important as can be plainly seen by contrasting what "Efficient Multimedia Distribution in Source Constraint Networks" teaches to what real-world cable TV systems employ. While many cable TV systems do not seek to be P2P networks, the demands beyond pure CDN (Content Delivery Networks) are necessary to support the proliferation of interactive services including apps such as Face Book now run on cable TV set-top boxes. The below cable TV system topology that has been around for many years. As shown the topology is clearly a "Cascaded Mesh" topology, and thus is sub-optimal as this paper clearly highlights.



(Cisco Systems, "Networkers" at pg. 35) [3]

In such a cable TV system, a "super headend" is employed which is comparable to the "super node" in this paper. Further, while the above only shows one set of "Fiber Node" "leaves", this "leaf" structure is actually replicated *for each* of the "Primary Hub" and "Secondary Hub" nodes. Thus the marked disadvantage of the traditional cable TV system shown above is the fact that the Cascaded Mesh topology provides inferior performance.

4. Weaknesses of the Proposed Solutions / Additional Considerations

While I found "Efficient Multimedia Distribution in Source Constraint Networks" to be highly effective in meeting the key objectives listed above, I did find a few opportunities for additional considerations related to the objectives of the paper as follows:

A. Improved Throughput Efficiency. The abovementioned *small scale* testing was done using TCP exclusively. With cable TV companies having spent billions of dollars in network infrastructure cost, including head end, an additional area of study would seem to be identifying the protocols used by cable TV companies and finding additional improvements based on the protocols used by cable TV companies. While using protocols used by actual cable TV systems may not yield optimal results, improvements in existing systems would yield faster Return on Investment (ROI) versus the deployment of new systems.

B. Optimal Topology. Additional study would seem warranted related to applying the techniques taught by this paper including connecting the leaf "Fiber Nodes" in the cable TV system illustrated above. Likewise, the impact of providing links between "Hub" nodes and studying the impacts of employing the paper's findings seems warranted. In the real world, some of these interconnections may be able to be done via more cost effective microwave links versus dedicated fiber.

C. Optimal System Architecture. Simply as an observation, the paper notes the disadvantages of the super node architecture as follows:

Super Node Disadvantages
Can be a single point of failure.
Increased overhead.

Conclusion

In all, I found "Efficient Multimedia Distribution in Source Constraint Networks" to be very insightful and compressive paper related to the subject of optimizing: throughput efficiency, network topology, and system architecture. The paper's test and simulation results prove that the paper's techniques as effective. Overall, I found the paper paves the way for improvements in real-world systems such as cable TV systems as noted above.

References

[1] Thinh Nguyen, Krishnan Kolazhi, Rohit Kamath, "Efficient Multimedia Distribution in Source Constraint Networks", IEEE, date unknown.

[2] www.planet-lab.com (link no long active), PlanetLab is a global research network that supports the development of new network services.

[3] Cisco Systems, "Networkers", document 1168_05_2000, 2000.