International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878
Volume 1 Issue 1, September 2013

Network Optimization (Mobile Backbone) - MILP Approach

Gumaste S. V.[1], Kharat M. U.[2], V. M. Thakare[3]

[1]Research Scholar, SGBAU, Amravati, Maharashtra, India
[2]Professor & Head, Department of CSE, BKC, Nasik, Maharashtra, India
[3]Professor & Head, Department of CSE, SGBAU, Amravati, Maharashtra, India

Abstract: ***Bandwidth may refer to bandwidth capacity or available bandwidth in bit/s, which typically means the net bit rate or the maximum throughput of a logical or physical communication path in a digital communication system. In the available or existing bandwidth of an enterprise, how the enterprise can utilize this existing bandwidth (without increasing the bandwidth capacity) in an efficient way for all applications that an enterprise have. This problem is analogous to the resource (particularly processor management of Operating system) utilization in efficient way. Optimized use of bandwidth in the specific locality can effectively give solutions for bandwidth utilization problems. There is no single best practice in architecting such a network. The truth of the matter is that some measure of compromise is required, unless cost is not a factor. IT administrators and network architects must begin with a solid conceptual and empirical understanding of several component factors. An important quantity of interest in mobile backbone networks is the number of regular nodes that can be successfully assigned to mobile backbone nodes at a given throughput level. This paper develops a novel technique for maximizing this quantity in networks of fixed regular nodes using mixed-integer linear programming (MILP). The MILP-based algorithm provides a significant reduction in computation time compared to existing methods and is computationally tractable for problems of moderate size.***

Keywords: Bandwidth, MILP (mixed integer linear programming), throughput, regular node, mobile backbone node

1. Introduction

In the current trends of education & similar applications use of internet / intranet and virtual classrooms are playing vital rule particularly for sharing of the expert recourses. Bandwidth is the only tool which enhances the communication over internet / intranet applications. Optimized use of bandwidth in the specific locality can effectively give solutions for bandwidth utilization problems. Objective of research work is to study and analyze various options for utilization of bandwidth optimally.

Communication takes a vital role in day today's activities of transforming education. More than 500 Million of people around the world use wireless communication. Wireless networks become the essential part of the human being. Due to sudden raise of mobile devices, yields an importance of wireless communication. Almost in essence communication (wireless) becomes the most important factor of the human being. A survey results out of 04 members one is having a mobile phone in India. Due to random increase in the number of users, performance of communication is challenging task for Engineers and scientists. Bandwidth is one of the tools which enhance the communication over internet / intranet applications.

On wireless networks, the bandwidth is shared between the clients, which mean that the available bandwidth always fluctuates. This paper focuses on a hierarchical network architecture called a mobile backbone network, in which mobile agents are deployed to provide long-term communication support for other agents in the form of a fixed backbone over which end-to-end communication can take place. Mobile backbone networks can be used to model a variety of multi-agent systems. For example, a heterogeneous system composed of air and ground vehicles conducting ground measurements in a cluttered environment can be appropriately modeled as a mobile backbone network, as can a team of mobile robotic agents deployed to collect streams of data from a network of stationary sensor nodes.

2. Optimizing Bandwidth for the Enterprise

There is no single best practice in architecting such a network. The truth of the matter is that some measure of compromise is required, unless cost is not a factor. IT administrators and network architects must begin with a solid conceptual and empirical understanding of several component factors. These include:

- What is the size and profile of the user base?
  This will include: Host users, Web servers or other resources resident on the LAN, Remote application services used by local hosts, VoIP or other streaming protocols
- What is the utilization profile?
  Are there multiple applications in constant use, or are there variances in traffic patterns based on time-of-day?
- What quality of service is required?
  The static content, such as passing Word or e-mail files, offers much more leeway in terms of throughput than does VoIP.
- Will the existing access routers support the required load?
  Number of WAN ports configurable on the platform, Processor capabilities, Maximum slot-table RAM (vendors generally specify 128 Mbps minimum to support full BGP

route announcements), Platform vendor's proprietary protocols.

In computer networking and computer science, digital bandwidth, network bandwidth or just bandwidth is a measure expressed in bit/s or multiples of it (kbit/s, Mbit/s).Bandwidth may refer to capacity or physical communication path in a digital communication system. The reason for this usage is that according to Hartley's law, the maximum data rate of a physical communication link is proportional to its bandwidth in hertz, which is sometimes called "analog bandwidth" in computer networking literature. Bandwidth may also refer to consumed bandwidth (bandwidth consumption), corresponding to achieved throughput, i.e. average data rate of successful data transfer through a communication path. This meaning is for example used in expressions such as bandwidth tests, bandwidth shaping, bandwidth management, bandwidth throttling, bandwidth cap, bandwidth allocation (for example bandwidth allocation protocol and dynamic bandwidth allocation), etc. An explanation to this usage is that digital bandwidth of a bit stream is proportional to the average consumed signal bandwidth in Hertz (the average spectral bandwidth of the analog signal representing the bit stream) during a studied time interval.

Digital bandwidth may also refer to average bit-rate after multimedia data compression (source coding), defined as the total amount of data divided by the playback time. Some authors prefer less ambiguous terms such as gross bit rate, net bit rate, channel capacity and throughput, to avoid confusion between digital bandwidth in bits per second and analog bandwidth in hertz.

The task of supporting integrated multi-rate multimedia traffic in a bandwidth poor wireless environment poses a unique and challenging problem for network managers. On wireless networks, the bandwidth is shared between the clients, which mean that the available bandwidth always fluctuates. Adaptive multimedia contents are required because of this fluctuation in order to optimize the wireless available bandwidth. In our last paper [1] , we described installation of proxy server optimizes 30-40% of utilized bandwidth hence it reduces the traffic to some extent.

Internet Connection Bandwidths

Below is a table showing the maximum bandwidth of different connection types to the internet [2]

Table 1: Maximum bandwidth of different connection types to the internet

Connection types	*Maximum bandwidth*
Modem / Dialup	56 Kbit/s
T1 1.544	Mbit/s
Ethernet 10	Mbit/s
Wireless 802.11b	11 Mbit/s
T3 43.232	Mbit/s
Wireless-G 802.11g	54 Mbit/s
Fast Ethernet	100 Mbit/s
OC3 155	Mbit/s
Wireless-N 802.11n	300 Mbit/s
OC12 622	Mbit/s
Gigabit Ethernet	1000 Mbit/s
OC48 2.5	Gbit/s
OC192 9.6	Gbit/s
10 Gigabit Ethernet	10 Gbit/s

3. Problem Statement

In this paper, we present sophisticated communication model similar to that described by Srinivas and Modiano [3]. Assumption made: Throughput (data rate) that can be achieved between a regular node and a mobile backbone node is a monotonically non-increasing function of both the distance between the two nodes and the number of other regular nodes that are also communicating with that particular mobile backbone node and thus causing interference. While our results are valid for any throughput function that is monotonically non-increasing in both distance and cluster size, it is useful to gain intuition by considering a particular example. One such example is the throughput function resulting from the use of a Slotted Aloha communication protocol in which all regular nodes are equally likely to transmit. In this, the throughput τ between regular node *i* and mobile backbone node *j* is given by,

$$\tau(A_j, d_{i,j}) = \frac{1}{|A_j|}\left(1 - \frac{1}{|A_j|}\right)^{(|A_j|-1)} \left(\frac{1}{d_{i,j}^{\alpha}}\right) \qquad (1)$$

Where $|A_j|$ is the number of regular nodes assigned to mobile backbone node *j*, $d_{i,j}$ is the distance between regular node *i* and mobile backbone node *j*, and α is the path loss exponent. As noted in Ref. [3], one can use the fact that ,

$$(1 - \frac{1}{c})^{(c-1)} \approx \frac{1}{e}$$

to obtain a simpler expression for the Slotted Aloha throughput function (for c > 0). Hence the throughput in simplified form is given by,

$$\tau(A_j, d_{i,j}) \approx \frac{1}{e|A_j|d_{i,j}^{\alpha}} \qquad (2)$$

Where e is the base of the natural logarithm. Building upon this continuous throughput model, we pose the mobile backbone network optimization problem as follows: given a set of N regular nodes distributed in a plane, our goal is to place K mobile backbone nodes, that can occupy arbitrary positions in the plane, while simultaneously assigning the regular nodes to the mobile backbone nodes, such that the effectiveness of the resulting network is maximized. In this work, the effectiveness of the resulting network is measured by the number of regular nodes that achieve throughput at least τ_{min}, (although other formulations such as: which maximizes the aggregate throughput achieved by all regular nodes) are possible. The particular choice of objective in this work is motivated by applications such as control over a network, in which a minimum throughput level is required, or sensing applications in which sensor measurements are of a known size. Thus, our objective is to maximize the number of regular nodes that achieve throughput at least τ_{min} .

4. Additional Assumptions

Because each "cluster" composed of a mobile backbone node and its assigned regular nodes operates at a different frequency than other clusters, each regular node can be assigned to a single mobile backbone node, and it is assumed that regular nodes assigned to one mobile backbone node encounter no interference from regular nodes assigned to other mobile backbone nodes. We also assume that mobile nodes need not be connected to one another. This assumption models the case in which mobile backbone nodes serve to provide a satellite uplink for regular nodes; this is the case, for instance, in hastily-formed networks that operate in disaster areas [4]. This assumption is also valid for the case in which the mobile backbone nodes are known to be powerful enough to communicate effectively over the entire problem domain. For cases in which the problem domain is so large that mobile backbone nodes have difficulty communicating with each other, it would be necessary to develop algorithms to ensure connectivity between the mobile backbone nodes. We considered "one-time" network design model means, once the mobile backbone nodes have been placed at their optimal positions, no improvement can be obtained by moving further and is also suitable for cases in which mobile backbone nodes are deployable, but cannot move once they have been deployed. We assume that the positions of regular nodes are known with complete accuracy, e.g., because the regular nodes are equipped with GPS. The problem of dealing with error in regular node position estimates is a topic of future research.

5. MILP Approach

Although the problem considered in this paper is similar to that encountered in cellular network optimization, the approaches taken herein differ from those in the cellular literature. Some approaches to cellular network optimization take base station placement to be given, then optimize over user assignment and transmission power to minimize total overall interference [5]-[8]. In contrast, we seek to optimize the network simultaneously over mobile backbone node placement and regular node assignment, without assuming variable transmission power capability on the part of the regular nodes and without limiting the placement of the mobile backbone nodes.

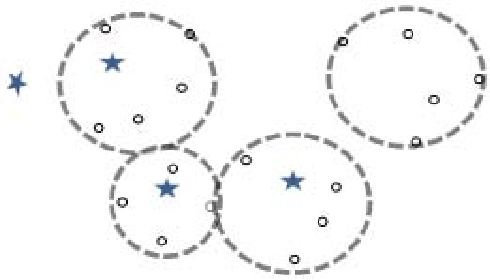

Figure 1: Typical mobile backbone network with mobile backbone and regular nodes.

A typical example which we considered in our work of an optimal solution to the simultaneous placement and assignment problem is shown in figure 1. Regular nodes are denoted by ○ and the mobile backbone nodes by ★. Regular nodes have been assigned to mobile backbone nodes such that the number of regular nodes that achieve throughput τ_{min} is maximized. In this example, clusters of regular nodes and mobile backbone nodes are of relatively small size, and the regular nodes are distributed intelligently among the mobile backbone nodes, with fewer regular nodes being allocated to mobile backbone nodes with larger cluster radii. In this example, all regular nodes have been successfully assigned to mobile backbone nodes. Mobile backbone network optimization problem stated as:

$\mathbb{R}_i$ - Locations of the regular nodes i = 1….N (regular nodes are stationary), τ_{min} - desired minimum throughput level, τ - throughput function and $\mathbb{M}_i$ -the selected locations of the mobile backbone nodes i = 1….K (the decision variables) and A - the assignment of regular nodes to mobile backbone nodes, this optimization problem can be stated as:

$\mathrm{Max}_{M,A} F_\tau(\mathbb{R}, \mathbb{M}, A, \tau_{min})$
Subject to $\mathbb{M}_i \in \mathbb{R}^2$ for I = 1,2,…….K
A $\in$ $\mathbb{A}$
Where A is the set of valid assignments, $F_\tau(\mathbb{R}, \mathbb{M}, A, \tau_{min})$ is number of regular nodes that achieve throughput level τ_{min}. Each mobile backbone node can be placed at the 1-center of its assigned regular nodes in an optimal solution while calculating throughput functions that are monotonically non-increasing in distance. The 1-center location for a set of regular nodes is the location that minimizes the maximum distance from the mobile backbone node to any of the regular nodes in the set. Consider a feasible solution to the mobile backbone network optimization problem, i.e., a solution in which K mobile backbone nodes are placed anywhere in the plane, (each regular node is assigned to at most one mobile backbone node) and each assigned regular node achieves throughput at least τ_{min}. Let A_k denote the set of regular nodes assigned to mobile backbone node k, for k=1,2…k, and let r_k denote the distance from mobile backbone node k to the most distant regular node in A_k. By our assumption that the solution is feasible, we know that $\tau(|A_k|, r_k) \geq \tau_{min}$. Now, modify the solution such that mobile backbone node k is placed at the 1-center of the set A_k, leaving the assignment A_k unchanged. By definition of the 1-center, the distance from every regular node in A_k to mobile backbone node k is no more than r_k. In particular, if

the distance from the mobile backbone node to the most distant regular node in A_k is now denoted by r_k', we know that,

$$\tau(|A_k|, r_k') \geq \tau(|A_k|, r_k) \geq \tau_{min}$$

since τ is a non-increasing function of distance. Thus, the modified solution in which the mobile backbone node is placed at the 1-center of its assigned regular nodes is feasible and has the same objective value as the original solution. Repeating the argument for the remaining mobile backbone nodes 1,2, … k, we can see that restricting the feasible set of mobile backbone node locations to the set of 1-center locations of all subsets of regular nodes does not reduce the maximum objective value that can be obtained. The network design problem that produces an optimal solution to the mobile backbone network optimization problem is constructed as follows. A source node, s, is connected to each node in the set of nodes N= {1,2,…N} (see Fig. 2). N represents the set of regular nodes. The arcs connecting s to *i* ∈ N are of unit capacity. Each node *i* ∈ N is in turn connected to a subset of the nodes in M = {N+1, N+2, … N+M}, where M is O(N^3). M represents the set of possible mobile backbone node locations, i.e., the 1-center locations of the subsets of regular nodes. Node *i* ∈ N is connected to node N+ *j* ∈ M if, and only if, regular node *i* is within the 1-center radius of location *j*. The arc connecting *i* to N + *j* is of unit capacity.

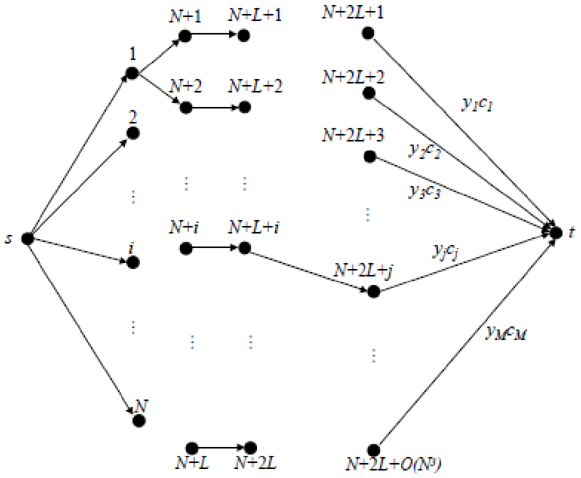

Figure 2: The joint placement and assignment problem for mobile backbone network design problem

Finally, each node in M is connected to the sink, t. The capacity of the arc connecting node N + *i* ∈ M to the sink is the product of a binary variable y_i, which represents the decision of whether to place a mobile backbone node at location *i*, and a constant c_i, which is the maximum number of regular nodes that can be assigned to a mobile backbone node at location i at the desired throughput level τ_{min}. The quantity c_i can be efficiently computed in one of two ways. For an easily-inverted throughput function such as the approximate Slotted Aloha function described by Eq. (2), one can simply take the inverse of the expression with respect to cluster size, evaluate the inverse at the desired minimum throughput level τ_{min}, and take the floor of the result to obtain an integer value for c_i. For the throughput function given by Eq. (2), we have

$$c_i = \left\lfloor \frac{1}{e\,\tau_{min}\, r_i^{\alpha}} \right\rfloor ; \qquad (3)$$

where r_i is the 1-center radius associated with 1-center location *i*. If the throughput function cannot easily be inverted with respect to cluster size, as is the case with the exact Slotted Aloha throughput function given in Eq. (1), one can perform a search for the largest cluster size $c_i \leq N$ such that $\tau(c_i, r_i) \geq \tau_{min}$. If K mobile backbone nodes are available to provide communication support for N regular nodes at given locations, and a throughput level τ_{min} is specified, the goal of the network design problem is to select K arcs incident to the sink and a feasible flow x such that the net flow through the graph is maximized. The network design problem can be solved via the following mixed-integer linear program (MILP), which we denote as,

$$\max_{x,y} \sum_{i=1}^{N} x_{si} \qquad (4a)$$

Subject to $\sum_{i=1}^{N} y_i = k$ (4b)

The objective of the Network Design MILP is to maximize the flow x through the graph (Eq. (4a)). The constraints state that K arcs (mobile backbone node locations (4b)) must be selected [9].

The geometry of the mobile backbone network problem is described by the arcs connecting node sets N and M, while both the throughput function and the desired minimum throughput level are captured in the capacities of the arcs connecting nodes in M to the sink, t. Any feasible placement of mobile backbone nodes and assignment of regular nodes is associated with a feasible solution to the network design problem with the same objective value; likewise, any integer feasible solution to the network design problem yields a feasible placement and assignment in the mobile backbone network optimization problem, such that the number of regular nodes assigned is equal to the volume of flow through the network designed graph.

6. Results

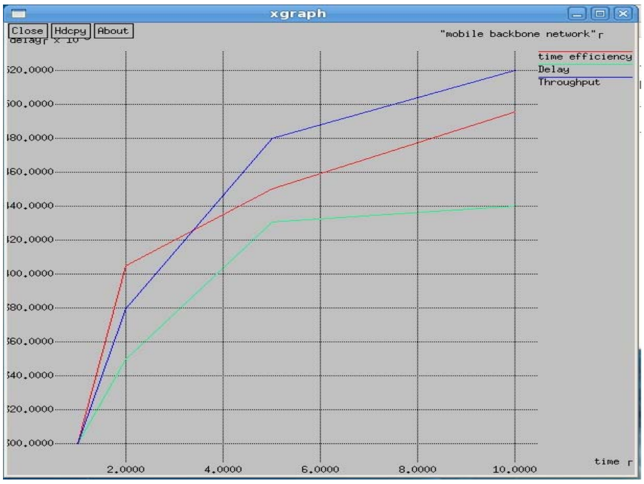

Figure 3: Delay V/s Throughput and Time efficiency

7. Conclusion

Based on simulation results, we conclude that the MILP based approach provides a considerable computational advantage over existing techniques for mobile backbone network optimization. This approach has been successfully applied to a problem in which a maximum number of regular nodes are to be assigned to mobile backbone nodes at a given level of throughput, and to a related problem from the literature in which all regular nodes are to be assigned to a mobile backbone node such that the minimum throughput achieved.

References

[1] S. V. Gumaste, Dr. Kharat M .U., Dr. V. M. Thakare, Mr. Aditya D.P. “Proxy Server Experiment and the Behavior of the Web” International Journal of Advanced Research in Computer Science, Volume 4, No. 2, Jan-Feb 2013
[2] http://searchnetworking.techtarget.com
[3] Srinivas and E. Modiano, “Joint node placement and assignment for throughput optimization in mobile backbone networks,” To appear in Proc. IEEE INFOCOM’08, Apr 2008.
[4] Steckler, B. Bradford, and S. Urrea, “Hastily Formed Networks For Complex Humanitarian Disasters - After Action Report and Lessons Learned from the Naval Postgraduate School’s Response to Hurricane Katrina,” http://faculty.nps.edu/dl/HFN/documents/NPS_Katrina_AAR-LL_04-MAY-06.pdf, accessed Sept 2009.
[5] S. V. Hanly, “An algorithm for combined cell-site
[6] selection and power control to maximize cellular spread spectrum capacity,” IEEE Journal on Selected Areas in Communications, Vol. 13, No. 7, pp. 1332-1340, Sept. 1995.
[7] G. J. Foschini and Z. Milzanic, “A simple distributed autonomous power control algorithm and its convergence,” IEEE Transactions on Vehicular Technology, Vol. 40, pp. 641-646, 1993.
[8] R. Yates and C. Y. Huang, “Integrated power control and base station assignment,” IEEE Transactions on Vehicular Technology, Vol. 44, No. 3, pp.638-644, 1995.
[9] R. Mathar and T. Niessen, “Integrated power control and base station assignment,” Wireless Networks, Vol. 6, No. 6, pp. 421-428, Dec. 2000.
[10] Craparo, Emily M., Jonathan P. How, and Eytan Modiano. “Throughput Optimization in Mobile Backbone Networks.” IEEE Transactions on Mobile Computing 10 (2011): 560-572.

Author Profile

S. V. Gumaste, BE (CSE), ME (CSE), was graduated at BLDE Associations College of Engineering & Technology, Bijapur (Karnataka University , Dharwar), completed his post graduation from COE, Badnera (Sant Gadge Baba Amravati University , Amravti).

Dr. M. U. Kharat, BE, M S, Ph.D. was educated at Amravati University. Presently he is working at the Institute of Engineering, Bhujbal Knowledge City, Nashik, Maharastra, India, as Professor & Head of the Computer Engineering Department.

Dr. V. M. Thakare, Head, Department of CSE, Sant Gadge Baba Amravati University, Amravati. He has worked in various capacities in academic institutions at the level of Professor, Head of Computer Engineering Department. His areas of interest include Digital image/Signal Processing, Computer Networks, and the Internet.