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Efficient Resource Allocation for Wireless Multicast in Heterogeneous Networks

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***Abstract*— In this paper, we first comment that the bandwidth consumption in the shortest path tree can be reduced in the heterogeneous wireless networks because the routing of the shortest path tree here is more flexible. The shortest path tree in the heterogeneous wireless networks consists of two parts. The first one is composed of the cell and the wireless technology chosen by each mobile host. The second one is comprised of the wired links that connect the root of the tree and the chosen cells. Therefore, we can change the routing of the shortest path tree by selecting different cells and wireless technologies for the mobile hosts to reduce the bandwidth consumption. Explicitly, we formulate in this paper the selection of the cell and the wireless technology for each mobile host as an optimization problem, which is denoted as the Cell and Technology Selection Problem (CTSP) in the heterogeneous wireless networks for multicast communications. The problem is to select the cell and the wireless technology for each group member to minimize the total bandwidth cost of the shortest path tree. We design a mechanism, which includes an Integer Linear Programming (ILP) formulation, a distributed algorithm, and a network protocol, to solve the CTSP. We use ILP to formulate the CTSP, and the network operator can use our ILP formulation to find the optimal solution for network planning. We show that CTSP is NP-hard, which, in turn, justifies the necessity of designing efficient algorithms for suboptimal solutions. We devise an algorithm LAGRANGE, which is based on Lagrangean relaxation on our ILP formulation.**

***Keywords*— Heterogeneous networks, wireless**

1. INTRODUCTION

Multicast is an efficient way for one-to-any and many to-many communications. Each multicast group owns a set of members, and each member can be a sender or a receiver of the group. The sender in a multicast group delivers data in a multicast tree to all receivers of the group. Current Internet Protocol (IP) multicast routing protocols adopt the shortest path trees for data delivery .The path from the root of the shortest path tree to each member must be the shortest path in the network. In other words, the routing of the shortest path tree is fixed once the root and all group members have been determined. As a consequence, the bandwidth consumption in an IP multicast tree will not be able to be reduced in wired networks

Each host (and in fact each application on the host) that wants to be a receiving member of a multicast group (i.e. receive data corresponding to a particular multicast address) must use the Internet Group Management Protocol (IGMP) to join. Adjacent routers also use this protocol to communicate.In unicast routing, each router examines the destination address of an incoming packet and looks up the destination in a table to determine which interface to use in order for that packet to get closer to its destination. The source address is irrelevant to the router

IP Multicast is a technique for one to many communications over an IP infrastructure. It scales to a larger receiver population by not requiring prior knowledge of who or how many receivers there are. Multicast uses network infrastructure efficiently by requiring the source to send a packet only once, even if it needs to be delivered to a large number of receivers. The nodes in the network take care of replicating the packet to reach multiple receivers only where necessary. The most common low-level protocol to use multicast addressing is UDP. By its nature, UDP is not reliable--messages can be lost or delivered out of order. Reliable multicast protocols such as PGM have been developed to add loss detection and retransmission on top of IP Multicast.Key concepts in IP Multicast include an IP Multicast group address, a multicast distribution tree and receiver driven tree creation.An IP Multicast group address is used by sources and the receivers to send and receive content. Sources use the group address as the IP destination address in their

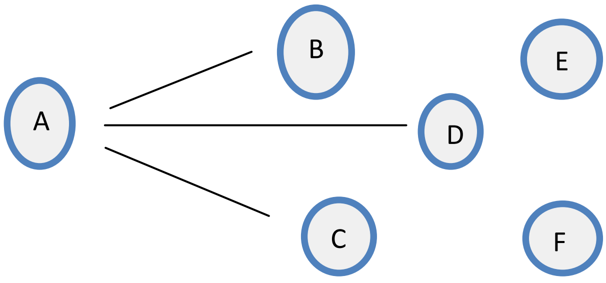


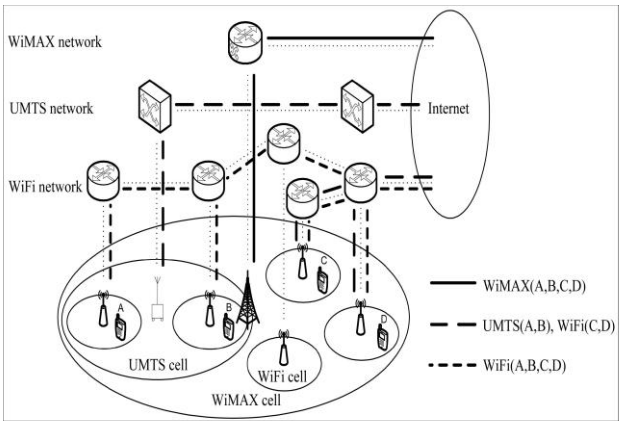
Fig1.1: Demonstration of multicasting technique

Data packets. Receivers use this group address to inform the network that they are interested in receiving packets sent to that group. For example, if some content is associated with group 239.1.1.1, the source will send data packets destined to 239.1.1.1. Receivers for that content will inform the network that they are interested in receiving data packets sent to the group 239.1.1.1. The receiver "joins" 239.1.1.1. The protocol used by receivers to join a group is called the Internet Group Management Protocol or IGMP.

Previous works also address the protocol design, reliable multicast, and other practical issues for homogeneous wireless networks. Alrabiah and Aljadhai find a low-cost multicast tree, instead of the shortest path tree, in homogeneous wireless networks. A new member reduces the cost of the tree by connecting to the closest member and reduces the handoff delay by pre establishing multicast paths to all neighboring cells. However, resource allocation among heterogeneous wireless networks has not been addressed in the previous works. We believe that it is an important issue because current ISPs tend to operate multiple wireless networks and multi radio handsets and PDAs are appearing in the markets. The path from the root of the shortest path tree to each member must be the shortest path in the network. Shortest path tree is fixed once the root and all group members have been determined Bandwidth consumption in an IP multicast tree will not be able to reduce in wired networks. The mobility of group members and dynamic group membership makes the IP multicast protocol to be unstable.

Multicast is an efficient way for one-to-many and many to-many communications. Each multicast group owns a set of members, and each member can be a sender or a receiver of the group. The sender in a multicast group delivers data in a multicast tree to all receivers of the group. Current Internet Protocol (IP) multicast routing protocols adopt the shortest path trees for data delivery. The path from the root of the shortest path tree to each member must be the shortest path in the network. In other words, the routing of the shortest path tree is fixed once the root and all group members have been determined. As a consequence, the bandwidth consumption in an IP multicast tree will not be able to be reduced in wired networks. we first comment that the bandwidth consumption in the shortest path tree can be reduced in the heterogeneous wireless networks because the routing of the shortest path tree here is more flexible. The shortest path tree in the heterogeneous wireless networks consists of two parts. The first one is composed of the cell and the wireless technology chosen by each mobile host. The second one is comprised of the wired links that connect the root of the tree and the chosen cells. Therefore, we can change the routing of the shortest path tree by selecting different cells and wireless technologies for the mobile hosts to reduce the bandwidth consumption Consider the scenario in Fig. 1.2 as an example, where mobile hosts A, B, C, and D are the members of the multicast group. The example presents three different shortest path trees to serve the four mobile hosts. The first one uses a WiMax cell to serve the four mobile hosts. The second one uses a Universal Mobile Telecommunications System (UMTS) cell to serve mobile hosts A and B and two WiFi cells to serve mobile hosts C and D. The third one uses four WiFi cells to serve the four mobile hosts. Therefore, this example shows that the routing of the shortest path tree in the heterogeneous wireless networks is not unique.

Fig 1.2: Demonstration of heterogeneous networks



A new member reduces the cost of the tree by connecting to the closest member and reduces the handoff delay by pre establishing multicast paths to all neighboring cells. Explicitly, we formulate in this paper the selection of the cell and the wireless technology for each mobile host as an optimization problem, which is denoted as the Cell and Technology Selection Problem (CTSP) in the heterogeneous wireless networks for multicast communications. The problem is to select the cell and the wireless technology for each group member to minimize the total bandwidth cost of the shortest path tree. We design a mechanism, which includes an Integer Linear Programming (ILP) formulation, a distributed algorithm, and a network protocol, to solve the CTSP.

We use ILP to formulate the CTSP, and the network operator can use our ILP formulation to find the optimal solution for network planning. We show that CTSP is NP-hard, which, in turn, justifies the necessity of designing efficient algorithms for suboptimal solutions. We devise an algorithm LAGRANGE, which is based on Lagrangean relaxation on our ILP formulation.

We adopt the Lagrangean relaxation in our algorithm, instead of other optimization techniques, due to the following reasons: First, our algorithm decomposes the Original problem into multiple sub problems such that each sub problem can be solved by each member and base station individually. In other words, the algorithm can be implemented in a distributed manner, and the important merit of the LAGRANGE algorithm enables us to design a network protocol accordingly. Second, the algorithm adapts to the change of the group membership and the mobility of group members.

The algorithm iteratively reduces the bandwidth consumption according to the current group membership and the location of group members. Third, the algorithm provides the lower bound on the total bandwidth cost of the optimal shortest path tree, where the optimal shortest path tree is the shortest path tree with the optimal selection of the cell and the wireless technology for each member. For the multicast group with a large number of members, the lower bound obtained by our algorithm provides the benchmark for comparing with any algorithm for the problem since using the ILP formulation to find the total bandwidth cost of a large optimal shortest path tree is computationally infeasible.

Overall, the contributions of this paper and the features of our mechanism are manifold:.

- `For each wireless technology, our mechanism reduces the number of cells used in the shortest path tree. Our algorithm clusters the mobile hosts such that nearby mobile hosts tend to use the same cell. Therefore, we can reduce the wireless bandwidth consumption even when the operator owns only one wireless technology. Our mechanism also optimizes the resource allocations for the operators with multiple wireless technologies. For a set of nearby mobile hosts, our mechanism uses a single larger cell or multiple smaller cells to serve these mobile hosts depending on the number of mobile hosts, the location of each mobile host, and the bandwidth cost of each wireless technology.
- Our mechanism is flexible since the bandwidth cost of each link and each cell can be assigned with no restriction. For example, we can concentrate on minimizing the wireless bandwidth if we assign a zero cost to each wired link and the cost model is suitable for the network with abundant wired bandwidth such as the optical network. Also, the flexible cost model enables the network operators to balance the load of both wireless cells and wired links. The network operators can increase the cost of link or cell when the link or cell is congested.
  - Our mechanism is transparent to the IP multicast routing protocols. The shortest path tree is created by joining the multicast group with the IP multicast routing protocols after each member has selected the cell and the wireless technology according to our mechanism. We thereby require no modification on the current IP multicast routing protocols.
  - Our mechanism supports the dynamic group membership. Our protocol reduces the total bandwidth cost according to the current group membership. When some mobile hosts join or leave a multicast group, each mobile host of the multicast group can adaptively initiate a horizontal or vertical handover to reduce the bandwidth consumption in the current shortest path tree.

II. EXISTING SOLUTION

Previous works also address the protocol design, reliable multicast, and other practical issues for homogeneous wireless networks. Alrabiah and Aljadhai find a low-cost multicast tree, instead of the shortest path tree, in homogeneous wireless networks. A new member reduces the cost of the tree by connecting to the closest member and reduces the handoff delay by pre establishing multicast paths to all neighboring cells. However, resource allocation among heterogeneous wireless networks has not been addressed in the previous works. We believe that it is an important issue because current ISPs tend to operate multiple wireless networks and multi radio handsets and PDAs are appearing in the markets. The path from the root of the shortest path tree to each member must be the shortest path in the network. Shortest path tree is fixed once the root and all group members have been determined Bandwidth consumption in an IP multicast tree will not be able to reduced in wired networks.The mobility of group members and dynamic group membership makes the IP multicast protocol to be unstable.

2.1 Disadvantages of Existing System

1. The shortest path in the multicast tree is fixed
2. The bandwidth consumption in IP multicast tree will not be able to reduced
3. The mobility of group members and dynamic group membership makes the IP multicast protocol to be unstable.

III. PROPOSED SOLUTION

In this paper, we first comment that the bandwidth consumption in the shortest path tree can be reduced in the heterogeneous wireless networks because the routing of the shortest path tree here is more flexible. The shortest path tree in the heterogeneous wireless networks consists of two parts. The first one is composed of the cell and the wireless technology chosen by each mobile host. The second one is comprised of the wired links that connect the root of the tree and the chosen cells. Therefore, we can change the routing of the shortest path tree by selecting different cells and wireless technologies for the mobile hosts to reduce the bandwidth consumption.

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We adopt the Lagrangean relaxation in our algorithm, instead of other optimization techniques, due to the following reasons: First, our algorithm decomposes the original problem into multiple subproblems such that each subproblem can be solved by each member and base station individually. In other words, the algorithm can be implemented in a distributed manner, and the important merit of the LAGRANGE algorithm enables us to design a network protocol accordingly. Second, the algorithm adapts to the change of the group membership and the mobility of group members. The algorithm iteratively reduces the bandwidth consumption according to the current group membership and the location of group members. Third, the algorithm provides the lower bound on the total bandwidth cost of the optimal shortest path tree, where the optimal shortest path tree is the shortest path tree with the optimal selection of the cell and the wireless technology for each member. For the multicast group with a large number of members, the lower bound obtained by our algorithm provides the benchmark for comparing with any algorithm for the problem since using the ILP formulation to find the total bandwidth cost of a large optimal shortest path tree is computationally infeasible.

3. 1 Assumptions and key terms

The mobile hosts considered in this paper are the members of a multicast group. A cell covers a mobile host if the mobile host is within the transmission range of the base station of the cell. Let a cell be a candidate cell if the cell covers at least one mobile host. A node or link x is downstream to another node or link y in the shortest path tree if y is on the path from the root of the tree to x. A subtree that is downstream to a link e contains link e and every node and link that is downstream to e in the shortest path tree. For simplicity, the selection of the cell for each mobile host means the selection of both the cell and the wireless technology in the rest of the paper.

The notations in this paper analysis is summarized as follows:

- **C**: the set of cells in the heterogeneous wireless networks.
- **E**: the set of links in the shortest path from each candidate cell to the root of the tree.
- **M**: the set of mobile hosts in the network.
- **Mc**: the set of mobile hosts covered by cell **c, c∈C**.
- **Cm**: the set of cells covering mobile host **m, m∈M, Cm⊆C**. If mobile host m selects cell c manually, we let the set **Cm** contain only a cell **c**.
- **Cu**: the set of cells that is downstream to node u in the shortest path tree **Cu⊆C**.
- **Ec**: the set of links in the shortest path from cell c to the root of the tree **Ec⊆E**.
- **Eu**: the set of links those are downstream to node u in the shortest path tree **Eu⊆E**.
- **eu;v**: the link from node **u** to **v**, **eu;v∈E**.
- **bc**: the bandwidth cost of cell **c, c ∈ C.**
- **bu;v**: the bandwidth cost of link **eu;v, eu;v ∈E**.
- **cu;v**: the cell with the base station **v** connected to link **eu;v, cu;v∈C,eu;v∈E**.
- **r**: the root of the shortest path tree.

3.2 INTEGER LINEAR PROGRAMMING

We use ILP to model CTSP. The ILP formulation can find the optimal shortest path tree in the heterogeneous wireless networks with any existing commercial software.

- The objective function of ILP formula

$$\text{Min}\sum_{C\in C} bc \times \sigma c + \sum_{eu,v\in E} bu,v \times \lambda u,v$$

Constraints

- $\Pi m,c = 1$,if mobile host selects any of the cell
- $\sigma c=1$,if cell c is used in the shortest path
- $\lambda u,v=1$,if link eu,v is used in the shortest path

Our constraints adopt a bottom-up manner. We first let each mobile host choose a cell. Once a cell is selected by any mobile host, the cell joins the shortest path tree.

- The first constraint guarantees that each mobile host selects one cell. For each mobile host m, the constraint enforces that Πm,c of exactly one cell c is 1.
- The second constraint enforces that a cell is used in the shortest path tree if it is selected by any mobile host. If Πm,c of any mobile host m and any cell c is 1,the inequality guarantees that σc must also be set as 1, and even the case that -Πm,c of another member -m is zero does not contradict the constraint.
- The third constraint states that a link is used in the shortest path tree if it is on the path from any selected cell to the root of the tree. When σc is 1 for a cell c, the inequality enforces λu, v to be set as 1 for every link eu;v between c and the root of the tree.

VI. DESIGN OF LAGRANGE ALGORITHM

In this we propose an algorithm for CTSP. The LAGRANGEAN algorithm is based on Lagrangean relaxation on our ILP formulation. The LAGRANGEAN algorithm has the following advantages:

- The algorithm can be implemented in a distributed manner. Each mobile host owns a cost for each covering cell and selects the cell with the smallest cost. The wireless networks compute and update the cost in a distributed manner to reduce the total bandwidth cost of the shortest path tree. No centralized server is required to maintain the group membership, the network topology, and the location of each mobile host. Therefore, the algorithm is easier to be integrated with the current IP multicast service model and protocols.

- The algorithm iteratively reduces the total bandwidth cost of the shortest path tree according to the current group membership and the set of cells covering the mobile hosts. In other words, the algorithm adapts to the dynamic join and leave of mobile hosts in a multicast group and the mobility of members.
- The algorithm provides a lower bound on the total bandwidth cost of the optimal solution to the CTSP. The lower bound can be used for comparing with the solution obtained by any algorithm for the problem.

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Sub problem 1:

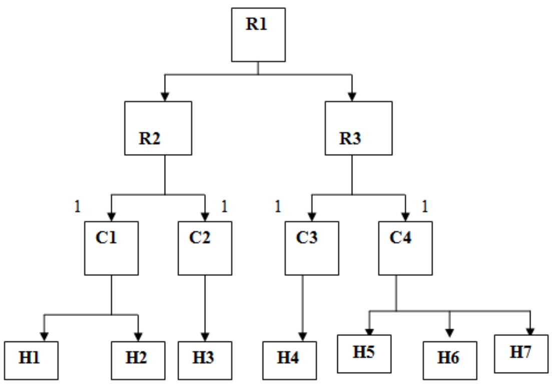

Fig: Sub problem 1

Above Figure shows the network topology with three routers, four cells, and seven mobile hosts. The wire line and wireless costs are both 1. A mobile host is covered by the cell if it connects to the cell with a wireless link. The mobile hosts are connected to the cells randomly. In the implementation each and every cell generates a random number if a new mobile host is entered into the network. Then the mobile host checks which value is lesser, based on that it will connects to the cell which generates the lesser value.

Sub problem 2:

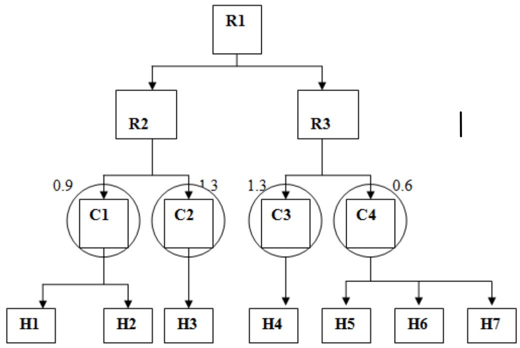

Fig: sub problem 2

Above fig shows the first iteration of the LAGRANGE algorithm. The value beside each wireless link is the cost of the cell for the mobile host. A wireless link is represented by a solid line if the mobile host chooses the cell in the first sub problem. A cell is represented by a solid circle if the cell is selected in the second sub problem.. A wire line link is represented by a solid line if the link is adopted in the shortest path tree of CTSP for data delivery.

Sub Problem 3:

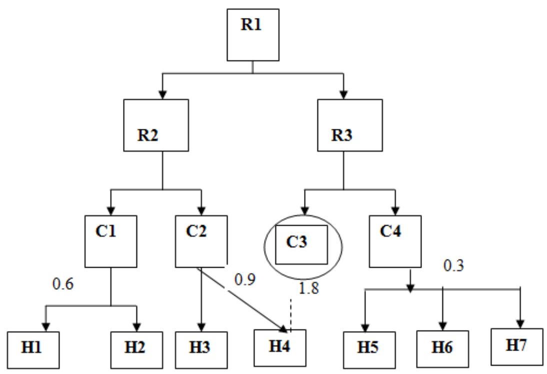

Fig: Sub Problem 3

Above fig shows the second iteration of the LAGRANGE algorithm. The value beside each wireless link is the cost of the cell for the mobile host. A wireless link is represented by a solid line if the mobile host chooses the cell in the second sub problem. A wireless link is represented by a doted line if the mobile host chooses the cell in the first sub problem .A cell is represented by a solid circle if the cell is not selected in the second sub problem. A wire line link is represented by a solid line if the link is adopted in the shortest path tree of CTSP for data delivery.

4.1 INTEGER LINEAR PROGRAMMING

We use ILP to model CTSP. The ILP formulation can find the optimal shortest path tree in the heterogeneous wireless networks with any existing commercial software.

- The objective function of ILP formula

$$\text{Min}\sum_{C\in C} bc \times \sigma c + \sum_{eu,v\in E} bu,v \times \lambda u,v$$

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2. σc=1 ,if cell c is used in the shortest path
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4.2 LAGRANGEAN ALGORITHM

- Langrangean relaxation problem is divided into two parts
- Each part owns one objective function
- The objective function of the first sub problem is given as follows

Min Σ Σ µm,c πm,c , (the constraint is it always 1 if
M€M c€C mobile host selects cell in shortest path)

- Second sub problem calculates the net cost of each and every link
- δu,v denote the minimum net cost of the sub tree that includes link eu,v and the sub tree rooted at v.
- δu,v can be calculated by the formula

δu,v=min{ 0,bcu,v + bu,v - Σ µm,cu,v}

- bu,v : The bandwidth cost of link eu,v
- Cu,v: The cell with the base station v connected to link eu,v
- bcu,v: The bandwidth cost of the cell with the base station v connected to link eu,v
- µm,cu,v: The number of mobile hosts covered by cell C

4.3 CELL AND MOBILE TECHNOLOGY

SELECTION PROBLEM

- Initially the lagrangean algorithm assigns unit cost to each cell for each member, and there by select any cell

Let µm,c ← 1, σc ← 1,πm,c ← 1

- Each member there by can select a cell having less cost

cm←min {µm,c}

- Our langrangean algorithm iteratively reduces the total bandwidth cost of the shortest path tree at each iteration by using the formula

δU,v←bcu,v +bu,v - Σ µm,cu,v
m,cu,v€cm

m,cu,v ← Number of mobile hosts covered by
each cell

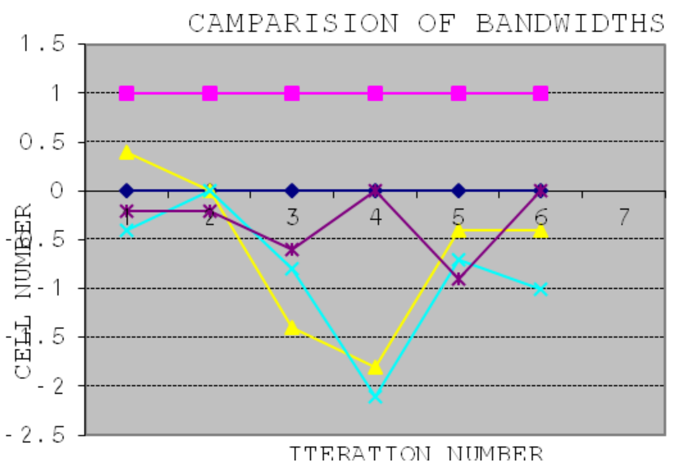
- Check whether (1)πm,c - σc >0
(2) Πm,c - σc<0
- If πm,c - σc >0 then the algorithm increases the cost of mobile host µm,c by ε
- If πm,c - σc <0 then the algorithm decreases the cost of mobile host µm,c by ε
- Langrangean algorithm stops when it does not adjust the cost at last

if n≤N then the algorithm stops
n← number of iterations
N← Threshold value for number of iterations

We have to reduce the ε as the improvement of the shortest path tree becomes smaller

V.GRAPHS

5.1 GRAPH SHOWING REDUCTION OF BAND WIDTH



cells	iteration1	iteration2	iteration3	iteration4
cell1	1	0.4	-0.4	-0.2
cell2	1	0	0	-0.2
cell3	1	-1.4	-0.8	-0.6

cell4	1	-1.8	-2.1	0
cell5	1	-0.4	-0.7	-0.9
cell6	1	-0.4	-1	0

5.2 GRAPH SHOWING REDUCTION OF NUMBER OF CELLS USED

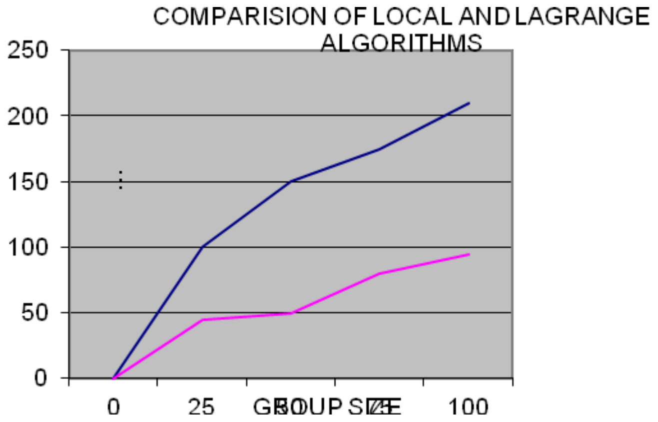


FIG (a),(b): Results showing reduction of total bandwidth cost and number of cells used by using Lagrangean algorithm.

GROUP SIZE	0	25	50	75	100
LOCAL (BANDWIDTH COST)	0	100	150	175	210
LAGRANGE (BANDWIDTH COST)	0	45	50	80	95

We can clearly in the above graphs by using the langrangean algorithm we reduce the total bandwidth cost of the network in (a) and in (b) we reduce the number of cells used in the network. This simulation results shows what the motto of the paper is.The main motto of our paper is to reduce the bandwidth cost and also reduce the number of cells used.

VI. CONCLUSION

we have proposed a new mechanism for reducing the total bandwidth cost of the IP multicast tree by adaptively selecting the cell and the wireless technology for each mobile host. We model the selection of the cell and the wireless technology for each mobile host as an optimization problem. We use ILP to formulate the optimization problem and show that the problem is NP-hard. The network operator can use the ILP formulation to find the optimal solution for network planning in small wireless networks. We design an algorithm based on Lagrangean relaxation and devise a distributed protocol based on the algorithm.

Our algorithm iteratively reduces the total bandwidth cost of the shortest path tree. Our protocol supports the dynamic group membership and mobility of members. Moreover, our protocol requires no modification on the current IP multicast routing protocols. Our simulation results show that our mechanism can effectively save the network bandwidth compared with the traditional IP multicast.

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