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USING INTEGER LINEAR PROGRAMMING FOR TO SOLVE CELL AND TECHNOLOGY SELECTION PROBLEM

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Abstract: - A bandwidth-efficient multicast mechanism for heterogeneous wireless networks. We reduce the bandwidth cost of an Internet protocol (IP) multicast tree by adaptively selecting the cell and the wireless technology for each mobile host to join the multicast group. Our mechanism enables more mobile hosts to cluster together and leads to the use of fewer cells to save the scarce wireless bandwidth. Besides, the paths in the multicast tree connecting to the selected cells share more common links to save the wireline bandwidth. Our mechanism supports the dynamic group membership and offers mobility of group members. Moreover, our mechanism requires no modification to the current IP multicast routing protocols. We formulate the selection of the cell and the wireless technology for each mobile host in the heterogeneous wireless networks as an optimization problem. We use integer linear programming to model the problem and show that the problem is NP-hard. To solve the problem, we propose a distributed algorithm based on Lagrangian relaxation and a network protocol based on the algorithm. The simulation results show that our mechanism can effectively save the wireless and wireline bandwidth as compared to the traditional IP multicast.

Keywords – IP, bandwidth, wireless technology, linear programming.

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1. INTRODUCTION

The success of wireless and mobile communications in the 21st century has resulted in a large variety of wireless technologies such as second and third-generation cellular, satellite, Wi-Fi, and Bluetooth. The heterogeneous wireless networks combine various wireless networks and provide universal wireless access. The leading wireless companies in some countries have operated networks with multiple wireless technologies, such as T-Mobile in the United States, British Telecom in the United Kingdom, Orange Telecom in France, NTT DoCoMo in Japan, and Chunghwa Telecom in Taiwan. The number of such Companies would increase because the standards for operators to provide seamless services in networks with multiple wireless technologies have been proposed by the Third-Generation

Partnership Project (3GPP) and Unlicensed Mobile Access (UMA). In addition, users in the heterogeneous wireless networks are usually covered by more than one cell to avoid connection drop and service disruption. More mobile terminals in the wireless networks are likely to own multiple wireless technologies. Therefore, the heterogeneous wireless networks provide the mobile hosts with many choices for the cells and wireless technologies to access the Internet.

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.

1.1 WIRELESS TECHNOLOGY

Wireless technology, which uses electromagnetic waves to communicate information from one point to another, can be applied to computers and other electronic devices. Although wireless technologies have been used in specific applications for decades, wireless networks have recently become much more widespread due to better technology and lower prices. Once the IEEE first defined wireless standards in the late 1990's, wireless networking became feasible for a wide range of business and personal applications. Wireless networking offers various advantages over wired connections, including mobility, connectivity, adaptability, and ease of use in locations that prohibit wiring. Universities, airports, and major public places are currently taking advantage of wireless technology, and many businesses, health care facilities, and major cities are developing their own wireless networks. Since the cost of wireless networks has dropped dramatically in recent years, they are also becoming more popular in home computing. The excitement of wireless, obviously, is that you can dispense with all these wires. You don't need them to communicate. If you have a laptop and some kind of wireless modem, you can open up your laptop and spontaneously, at any given time, form a network with maybe 1,000 people on your campus or 100 people in your office building. This is what's called an ad hoc wireless network. There's no prior infrastructure. What makes them interesting is that they need to be very adaptive. For instance, in the morning there may only be 50 people in this building; in the afternoon, 100. So the number of nodes may change. The position of the nodes changes accordingly. But the network itself has to keep functioning.

It's a very volatile situation yet with enormous potential for all kinds of applications. Wouldn't it be great, for instance, if we could construct a huge wireless network that spans thousands or hundreds of thousands of nodes, if we could surround ourselves with communication and intelligence everywhere?

1.2 HETROGENEOUS MULTICAST NETWORK

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 Figure. 1.1 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 Wi-Fi cells to serve mobile hosts C and D. The third one uses four Wi-Fi 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. To the best of our knowledge, there is no related work about the selection of the cell and the wireless technology for each mobile host to build a bandwidth-efficient multicast tree in the heterogeneous wireless networks.

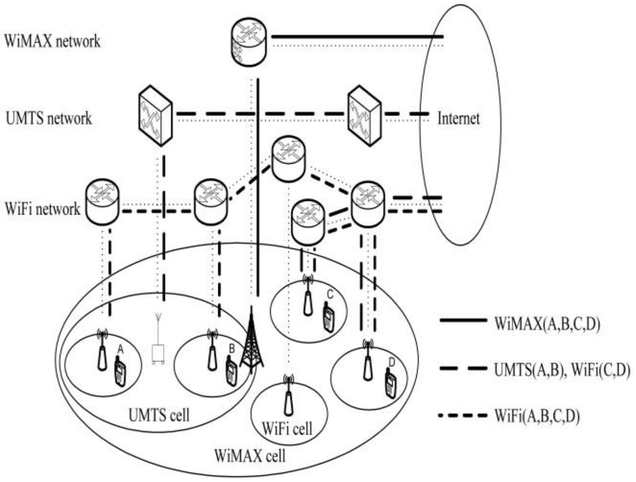

Figure1. Selecting different cells and wireless technologies for mobile hosts.

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.

2. AIM AND SCOPE OF PRESENT INVESTIGATION

2.1 AIM OF THE PRESENT INVESTIGATION

In this project we are dealing with resource allocations in heterogeneous multicast networks using a bandwidth-efficient multicast mechanism. Our mechanism enables more mobile hosts to cluster together and leads to the use of fewer cells to save the scarce wireless bandwidth. Besides, the paths in the multicast tree connecting to the selected cells share more common links to save the wire line bandwidth. Our mechanism supports the dynamic group membership and offers mobility of group members. We formulate the selection of the cell and the wireless technology for each mobile host in the heterogeneous wireless networks as an optimization problem. We use Integer Linear Programming to model the problem and show that the problem is NP-hard. To solve the problem, we propose a distributed algorithm based on Lagrangian relaxation and a network protocol based on the algorithm. The simulation results show that our mechanism can effectively save the wireless and wire line bandwidth as compared to the traditional IP multicast. This can be achieved through selecting the cell and the wireless technology for each mobile host to join the multicast group. As a result bandwidth cost of an internet protocol multicast tree will be reduced.

2.2 SCOPE OF THE PRESENT INVESTIGATION

The main aim of the project is to reduce the bandwidth cost of the multicast tree. The bandwidth cost is reduced by finding the shortest path. We implement Lagrangian Algorithm to find the shortest path. We propose a distributed algorithm based on Lagrangian relaxation and a network protocol based on the algorithm. The simulation results show that our mechanism can effectively save the wireless and wire-line bandwidth as compared to the traditional IP multicast.

2.2.1 EXISTING SYSTEM

To the best of our knowledge, there is no related work about the selection of the cell and the wireless technology for each mobile host to build a bandwidth-efficient multicast tree in the heterogeneous wireless networks. Most previous works for mobile multicast in the heterogeneous wireless networks focus on the efficient mechanisms to provide seamless handover between different networks and the related security issues. In addition, for video services, the network selection of cellular networks or Digital Video Broadcast - Handheld (DVB-H) for mobile users has been addressed.

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 re-establishing multicast paths to all neighbouring 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 multiradio handsets and PDAs are appearing in the markets. Consequently, in this paper, we propose a mechanism for reducing the bandwidth consumption in the shortest path tree by adaptively selecting the cell and the wireless technology for each mobile host in the heterogeneous wireless networks. The feature distinguishes our work from others.

2.2.2 PROPOSED SYSTEM

The aim of the proposed system is to reduce the bandwidth cost of an internet protocol multicast tree. This can be achieved through adaptively selecting the cell and the wireless technology for each mobile host to join the multicast group. This can be done through finding the shortest path. 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. 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.

3. ALGORITHM AND TECHNIQUES

3.1 LAGRANGE ALGORITHM

The LAGRANGE algorithm is based on Lagrangian relaxation on our ILP formulation. The LAGRANGE 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. The algorithm relaxes a constraint of our ILP formulation and transfers CTSP into the Lagrangian Relaxation Problem (LRP). The LRP owns a new objective function with the Lagrange multipliers and fewer constraints such that we can decompose the LRP into multiple sub problems, where each sub problem can be solved in a distributed manner. The members in our algorithm collaboratively construct the shortest path tree according to the solutions to the sub problems. Besides, the cost of each cell for each member is updated iteratively to reduce the total bandwidth cost of the shortest path tree according to the current group membership and the locations of members. Therefore, the algorithm is suitable for protocol design.

3.2 CELL AND TECHNOLOGY SELECTION PROBLEM

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 Lagrangian relaxation [21] on our ILP formulation.

We adopt the Lagrangian 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.

We show that the CTSP in the heterogeneous wireless networks for multicast communications is NP-hard because the Minimum Set Cover problem is a special case of the CTSP problem. In Minimum Set Cover, each set is assigned a cost and covers some elements. The problem is to select the sets with the minimum total cost such that every element is covered by at least one selected set. Therefore, Minimum Set Cover is the same as the CTSP if we connect each cell in the CTSP directly to the root with a zero-cost

Wire line link, where each cell and mobile host in the CTSP are just the set and element in Minimum Set Cover, respectively.

3.3 EXPERIMENTAL STUDIES

To the best of our knowledge, there is no related algorithm for CTSP in the previous works. Therefore, we compare the LAGRANGE algorithm with two other algorithms that can represent the reasonable user behaviours. In the first algorithm RAND, each mobile host randomly selects a cell. In the second algorithm LOCAL, each mobile host locally selects the wireless technology with the minimum bandwidth cost because the mobile host tends to spend the least monetary cost in this case. The mobile host selects the cell with the minimum distance to the base station if there is more than one cell with the minimum bandwidth cost. Moreover, we also compare the solution obtained by our algorithm with the optimal solution obtained by CPLEX with our ILP formulation in small wireless networks. In large wireless networks, we compare the solution obtained by our algorithm with the lower bound on the total bandwidth cost of the optimal shortest path tree, where we find the lower bound from the solution of the LRP.

The first constraint guarantees that each mobile host selects one cell.

The second constraint enforces that a cell is used in the shortest path tree if it is selected by any mobile host.

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.

DECOMPOSING AND SOLVING LRP

Here the Lagrangian Multiplier is nothing but the cost of the Cell C.

Besides, any feasible solution to CTSP must also act as a feasible solution to the LRP since the set of constraints of the LRP is a subset of the constraints of CTSP. Therefore, when we adopt the optimal solution to CTSP as the feasible solution both to the LRP and CTSP.

The optimal solution to the first sub-problem is to find the cell with the minimum cost for each mobile host m. The runtime of the algorithm for the first sub-problem is thereby $O(|M| |C|)$.

The objective function of the second problem is to minimize the net cost of all selected cells in the shortest path tree, and we have to find the best trade-off to select the cells.

4. RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 RESULTS FOR SMALLER WIRELESS NETWORKS

We first compare the solutions obtained by the LAGRANGE algorithm with the optimal solutions obtained by our ILP formulation with CPLEX. We simulate only small wireless networks because solving large ILP problems is computationally infeasible. The network is in a 25 km _ 25 km service area and has 36 hexagon cells. The base stations of every adjacent nine cells are connected to a router, and each router is connected to the gateway. The Bandwidth cost of each cell and link presents the total bandwidth cost and the number of cells used in the data tree and the control tree. The number of links used in the data tree and control tree. Our algorithm outperforms both RAND and LOCAL. Our algorithm saves about 40 percent of bandwidth cost. Besides, the total bandwidth cost obtained by our algorithm is very close to the optimal solution. Although our protocol maintains a control tree for each group, the total bandwidth cost of the control tree is smaller than the total bandwidth cost of the data trees obtained by RAND and LOCAL. The reason is that our protocol incrementally prunes the control tree to reduce the size of the tree.

4.1.2. RESULTS IN LARGER WIRELESS NETWORK

Our algorithm, at some iteration, generates the shortest path trees with slightly larger bandwidth costs than the trees in the previous iterations. The reason is that our algorithm, which is based on Lagrangian relaxation, searches the slightly worse solutions to avoid trapping in locally optimal solutions. The average bandwidth cost of a data tree slightly increases when a mobile host moves more frequently. However, the total bandwidth costs of the data tree and the control tree are still less than the total bandwidth cost of the data tree generated by RAND and LOCAL.

Our algorithm converges toward the optimal solution iteratively. The convergence time is correlated to the number of iterations and the time between two iterations, where the latter one can be assigned by the network operators. Therefore, given the mobility frequency of users, the network operators can set an appropriate period of time between two iterations for our algorithm. Ideally, the network operator can set a short period of time such that our algorithm finds the best solution before a mobile host hands over. However, this approach induces a large amount of overhead, since all iterations are performed within a short period of time. Therefore, the trade-off. The figure with a higher mobility corresponds to a larger interval between two iterations in our algorithm.

The reason is that each cell covers more mobile hosts such that our algorithm clusters the mobile host and requires fewer wireless cells and wireline links. However, the results of RAND and LOCAL are the same for different transmission ranges of the base stations. A mobile host in LOCAL still selects the cell in which the base station is closest, even though there are more cells covering the mobile host. The RAND and LOCAL algorithms cannot reduce the total bandwidth cost of a data tree because each mobile host individually and independently selects the cell, ignoring the possibility of sharing the bandwidth cost with adjacent mobile hosts.

Therefore, we believe that each cell in our algorithm can support more multicast groups because each group uses much fewer cells. Moreover, our algorithm uses less wireline bandwidth, even though we only minimize the consumption of the wireless bandwidth. The reason is that there are fewer cells in a data tree such that we need fewer links to connect to the cells.

4.2 PERFORMANCE ANALYSIS

4.2.1. TRANSIENT BEHAVIOR OF THE LAGRANGE ALGORITHM

To test the performance of our algorithm in different scenarios, we change the following parameters:

1. Group size.

The group size is the number of members, namely, mobile hosts, in a multicast group. We change the group size to test the scalability of our algorithm and protocol.

2. Transmission range of a base station.

For each wireless technology, the size of the overlapping area of adjacent cells is different when the transmissions range of a based station changes.

3. Bandwidth cost of each link and cell.

The network operators can assign a larger bandwidth cost to a wireless cell rather than a wire-line link. The network operators can also give a larger bandwidth cost to a congested link or cell to balance the traffic load in the networks. Besides, we also consider that every wire-line link is assigned a zero cost to represent the case that the network operators concern only the wireless bandwidth consumption.

We measure 100 samples in each scenario. The performance metrics in our simulation are listed as follows:

1. Total bandwidth cost of the data tree and the control tree.

The data tree is the shortest path tree for data delivery, and the control tree is the shortest path tree in our protocol to solve the second sub problem of the LRP in a distributed manner.

2. Number of links and cells in the data tree and the control tree.

The number of control messages and the number of nodes storing the agent of our protocol are proportional to the number of links and cells in the control tree.

Our algorithm, at some iteration, generates the shortest path trees with slightly larger Bandwidth costs than the trees in the previous iterations. The reason is that our algorithm, which is based on Lagrangian relaxation, searches the slightly worse solutions to avoid trapping in locally optimal solutions.

The total bandwidth costs of the data tree and the control tree are still less than the total bandwidth cost of the data tree generated by RAND and LOCAL. Our algorithm converges toward the optimal solution iteratively. The convergence time is correlated to the number of iterations and the time between two iterations, where the latter one can be assigned by the network operators. Therefore, given the mobility frequency of users, the network operators can set an appropriate period of time between two iterations for our algorithm.

Ideally, the network operator can set a short period of time such that our algorithm finds the best solution before a mobile host hands over.

However, this approach induces a large amount of overhead, since all iterations are performed within a short period of time. Therefore, the trade-off between the quality of the solution and the time between two intervals are shown. The figure with a higher mobility corresponds to a larger interval between two iterations in our algorithm.

In addition, the bandwidth cost is different from the bandwidth consumption. The bandwidth cost is proportional to the number of links and cells in a multicast tree. Since our protocol induces Only several control messages in each link and cell at each iteration, the bandwidth consumption in a control tree is much smaller as compared to the data tree.

In mobile IP, two network entities are defined to support users mobility namely; the home agent and the foreign agent. These two agents periodically send advertisement messages to their corresponding networks (i.e., home and foreign networks) to acknowledge the mobile of its present location. Based on these advertisement messages, and the present location of the mobile host, the mobile host decides whether it belongs to its home network or to a new foreign network.

If the mobile host discovers that it has migrated to a new foreign network, it sends a registration request to the corresponding new foreign agent to obtain a care-of-address.

In the same way, if the mobile host transmits data packets to its correspondent host, it uses the foreign agent for the tunnelling process to forward these data packets to the home agent for subsequent transmission to the correspondent host.

CONCLUSION

In this paper, 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 Lagrangian 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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