A Study on Routing Algorithm in Ubiquitous and Broadband Convergence Networks

Ubiquitous 및 Broadband Convergence Networks 환경에서의 Routing 알고리즘 연구

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by

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A Study on Routing Algorithm in Ubiquitous and Broadband Convergence Networks

A Dissertation

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A Study on Routing Algorithm in Ubiquitous and Broadband Convergence Networks

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Abstract

Over the past decade, the improvement of communications technologies and the rapid spread of WWW (World Wide Web) have brought on the exponential growth of users using Internet and real-time multimedia services like voice telephony, video conferencing, tele-immersive virtual reality, and Internet games.

In order to provide real-time multimedia services, the next generation convergence network must be equipped with DWDM based transmission network, which multiplex one fiber into various wavelengths to send much information. Whereas on purpose to control for both optical and electronic networks, Generalized Multi-Protocol Label Switching (GMPLS) has shown up and is currently under standardization at the Internet Engineering Task Force (IETF). Therefore IP/GMPLS over DWDM is emerging as a dominant technology for use in the next generation convergence backbone network.

This thesis suggests a multicast routing algorithm for multicast services in IP/GMPLS over DWDM network, which control the optical backbone network of the next generation convergence network.

In addition to the efficient control of DWDM-based backbone network, external

networks must be equipped with approximate control algorithms according to their applications. Especially, the ubiquitous sensor network shows proper solutions of what we want to gain at anytime and anyplace, in which it is mandatory to reduce the battery consumption of each sensor node in order to extend the whole network lifetime.

This thesis also proposes a new data aggregation algorithm for clustering distributed nodes in ubiquitous sensor networks, combining the random cluster head election technique in LEACH with DAG in TORA. Using the efficient DAG, the proposed data aggregation algorithm saves the radio energy dissipations of the transmitter and the receiver due to the short propagation distance.

Ⅰ. Introduction

Over the past decade, the improvement of communications technologies and the rapid spread of WWW (World Wide Web) have brought on the exponential growth of users using Internet and real-time multimedia services like voice telephony, video conferencing, tele-immersive virtual reality, and Internet games.

Moreover our country has 11.3 million broadband subscribers in a population of 48 million people. Now it plans to build a nationwide Internet access infrastructure capable of speeds between 50M bps (bits per second) and 100M bps by 2010. This project is called the Broadband Convergence Network (BcN). BcN will offer telecommunications, broadcasting and Internet access from a wide variety of devices. Therefore BcN is the next generation convergence network in order to use the quality guaranteed broadband multimedia service condensed with telecommunications, broadcasting, and Internet access at anytime and anyplace.

In order to provide real-time multimedia services, the next generation convergence network must be equipped with DWDM based transmission network, which multiplex one fiber into various wavelengths to send much information. Whereas on purpose to control for both optical and electronic networks, generalized multi-protocol label switching (GMPLS) has shown up and is currently under standardization at the Internet Engineering Task Force (IETF). Therefore IP/GMPLS over DWDM is emerging as a dominant technology for use in the next generation backbone network.

In order to provide various multimedia services, the multicast routing method supplies more efficient solution than the previously used unicast routing method in the respect of bandwidth utilization in the next generation convergence network. Therefore this paper suggests a multicast routing algorithm in order to provide multicast service in IP/GMPLS over DWDM network, which control the optical backbone network of the next generation convergence network.

To support multicast services at the Wavelength-Division Multiplexing (WDM) layer, the concept of the light-tree was introduced in [1], which is a point-to-multipoint extension of a lightpath (i.e., an all-optical WDM channel). The key advantage of light-tree is that only one transmitter is needed for transmission and intermediate tree links can be shared by multiple destinations. To support all-optical multicasting sessions efficiently, some nodes in DWDM networks need to have the light splitting capability [2]. A node with splitting capability can forward an incoming message to multiple output channels, and therefore is multicast-capable (MC). An MC node, however, is expensive to implement throughout the whole networks, so the concept of sparse-splitting was first introduced in [3]. With the sparse splitting capability, only small percentages of nodes in the networks are MC, and the rest are Multicast Incapable (MI). MI nodes can forward an input signal only to one of the output ports; thus it cannot serve as a branching node of a light-tree.

In order to provide the multicast services, some multicast routing algorithms were proposed based on Source-based tree and Steiner-based tree. In Source-based tree, a multicast tree was constructed to minimize the cost of individual paths from a source to each destination [3]. In [4], Steiner-based multicast methods were proposed to minimize the total cost of the tree. But the previous researches had following defaults. In the wide area networks, the destinations of a session are distributed over the globes, so the delay incurred in constructing the light tree will be very high. And the tree may need to be reconstructed, if a link or a node fails. Therefore it needs to have a simple procedure to add and delete a node from the existing multicast session.

To overcome these limitations, [5] proposed VS-based tree generation method. Using VS node that has both splitting and wavelength conversion capabilities, the node can transmit an incoming message to any number of output links on any wavelengths. And the setup time for VS-based multicast tree is much less compared to that of source-rooted multicast tree construction because each VS node should make reservations for the paths to support the multicast sessions prior to the multicast service requests. But as the number of VS nodes increases, the overheads due to the resource reservation for paths between VS nodes also increase, especially in the frequently used links, i.e., the critical links. In order to reduce the overheads in the critical links that affect the network performances, it needs a link-managing scheme between VS nodes throughout the networks [6].

To surmount this problem, we propose a new Multicast Routing and Wavelength Assignment method choosing a link that does not interfere too much with potential future multicast session requests, called Virtual Source-based Minimum Interference Path Multicast Routing (VS-MIPMR) [6-10].

Our work is inspired by the previously proposed Minimum Interference Routing (MIR) algorithm with traffic engineering in a multi-protocol label switching (MPLS) network [6-9]. Moreover, in [7] Multi-Wavelength Minimum Interference Path Routing (MW-MIPR) was proposed for an extension of MIR from the viewpoint of providing an appropriate traffic-engineering scheme through efficiently utilizing wavelengths by taking into consideration the potential future network's congestion states. Using MW-MIPR, this paper provides a new Multicast Routing and Wavelength Assignment method for multicast services, which efficiently uses the wavelength resources in comparison with VS-based tree generation method.

In addition to the efficient control of DWDM-based backbone network, external networks must be equipped with approximate control algorithms according to their applications. Especially, the ubiquitous sensor network shows proper solutions of what we want to gain at anytime and anyplace, in which it is mandatory to reduce the battery consumption of each sensor node in order to extend the whole network lifetime.

Data aggregation is one of the power saving strategies in the ubiquitous sensor network, combining the data that comes from many sensor nodes into a set of meaningful information. In LEACH, the useful data is aggregated to the cluster heads that are randomly selected and allocate the time scheduling to their cluster members [11]. But LEACH needs clustering formation overheads before performing the task and the nodes which are away from a cluster head consume much more transmission batteries comparing to the nodes close to the cluster head. In order to eliminate redundancy power consume in LEACH, TORA (Temporally-Ordered Routing Algorithm) technique [12] which builds a DAG (Directed Acyclic Graph) rooted at the destinations in ad hoc networks can be used. With DAG each cluster head can construct an efficient cluster rooted at itself in sensor networks.

Therefore This paper also proposes DAUCH data aggregation algorithm for clustering distributed nodes in ubiquitous sensor networks, combining the random cluster head election technique in LEACH with DAG in TORA. Using the efficient DAG, the proposed data aggregation algorithm saves the radio energy dissipations of the transmitter and the receiver due to the short propagation distance.

The rest of the paper is organized as follow: in section II, we review the state of previous routing researches in ubiquitous sensor and broadband convergence networks. We define a new data aggregation algorithm in ubiquitous sensor network in section III, and define a new multicast routing and Wavelength assignment algorithm, i.e., Virtual Source-based Minimum Interference Path Multicast Routing in broadband convergence networks in section IV. Experiment results showing effects of new algorithms and our conclusion are presented in section V and VI, respectively.

Ⅱ. The State of Previous Routing Research

1. The Analysis of Previous Routing Schemes in Ubiquitious Sensor Networks

Due to recent technological advances, the manufacturing of small and low-cost sensors has become technically and economically feasible. These sensors measure ambient conditions on the environment surrounding them and then transform these measurements into signals that can be processed to reveal some characteristics about phenomena located in the area around these sensors. A large number of these sensors can be networked in many applications that require unattended operations, hence producing a Ubiquitous Sensor Network (USN). In fact, the applications of USN are quite numerous. For example, USNs have profound effects on military and civil applications such as target field imaging, intrusion detection, weather monitoring, security and tactical surveillance, distributed computing, detecting ambient conditions such as temperature, movement, sound, light, or the presence of certain objects, inventory control, and disaster management. Deployment of a sensor network in these applications can be in random fashion (e.g., dropped from an airplane in a disaster management application) or manual (e.g., fire alarm sensors in a facility or sensors planted underground for precision agriculture). Creating a network of these sensors can assist rescuer operations by locating survivors, identifying risky areas, and making the rescue team more aware of the overall situation in a disaster area.

Typically, USNs contain hundreds or thousands of these sensor nodes, and these sensors have the ability to communicate either among each other or directly to an external base station. One of the main design goals of USNs is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques. Especially, the underlying network structure can play a significant role in the operation of the routing protocol in USNs. Figure 1 present this category based on the network structure.

The first category of routing protocols is the flat routing protocol, in which each node typically plays the same role and sensor nodes collaborate to perform the sensing task. The second category of routing protocol is the hierarchical or cluster-based routing method, in which higher-energy nodes can be used to process and send the information, while low-energy nodes can be used to perform the sensing in the proximity of the target.

In addition to the routing protocol, data aggregation also plays one of critical factors because the data on the field can be the same information. So data aggregation can reduce the redundant data transfer to save the limited node energies.

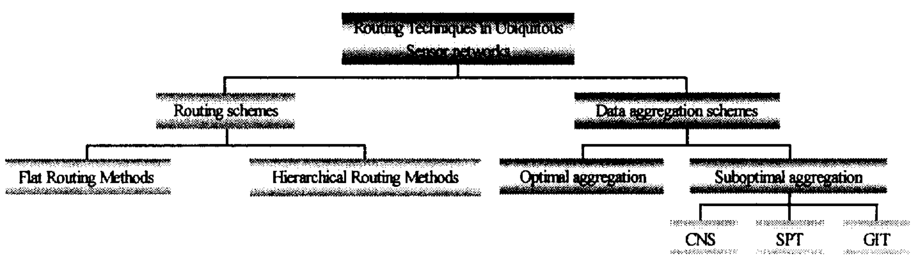


Figure 1. Routing technique structure in USNs

1.1 Routing Schemes

1) Flat Routing Method

Flat Routing Method is that all nodes in the fields exchange the information with each other in the equal position. There are some disadvantages that the specific node's battery consumption is high according to the traffic characteristic to send data to the sink when the event occurs and that the routing method is complex when the data are transferred to the corresponding node. But this method shows the optimal routing methods in the viewpoint of network, because all nodes establish the link connections without synchronizing and it performs the destination path establishment procedure without redundant overhead from the source to the destination. There are flooding, gossiping, SPIN, Directed Diffusion, GEAR, Rumor Routing, and SER routing method in flat routing methods of USNs.

1) Hierarchical Routing Method

Flat Routing Method is efficient in the small-scale networks because of its simple routing construction procedure. But the large the scale of network is, the much the quantity of routing information is. And there are long delays in sending the routing information from the remote sensor node and in transferring data from the remote source nodes. Therefore it needs a routing method in which all nodes can waste the equivalent battery in order to guarantee the long lifetime.

Hierarchical routing method was proposed to resolve such a problem, in which all nodes are partitioned into logical groups and each logical group has the head node that control the data traffic in the corresponding group. There are LEACH, TEEN, APTEEN, PEGASIS routing method in Hierarchical routing method of USNs

Table 1 summarizes the comparisons of Flat and Hierarchical Routing Methods according to the specific parameters.

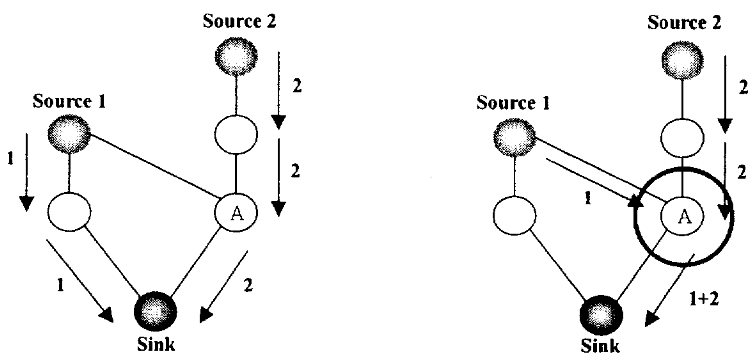
Table 1. Comparisons of Flat and Hierarchical Routing Methods

	Hierarchical Routing method	Flat Routing method
Scheduling	Reservation-based scheduling	Contention-based scheduling
Collision	Collisions avoided	Collision overhead present
Duty cycle	Reduced duty cycle due to periodic sleeping	Variable duty cycle by controlling sleep time of nodes
Aggregation point	Data aggregation by cluster head	Node on multi-hop path aggregates incoming data from neighbors
Complexity	Simple but non-optimal routing	Routing is complex but optimal
Requirement	Requires global and local synchronization	Links formed on the fly, without synchronization
Overhead	Overhead of cluster formation throughout the network	Routes formed only in regions that have data for transmission
Energy dissipation	Energy dissipation is uniform	Energy dissipation depends on traffic patterns
Fairness	Guarantee	Not guarantee

1.2 Data Aggregation Schemes

1) Data aggregation in sensor networks

Before starting the data aggregation techniques, we should investigate the routing models [13] that are assumed to consist of a single data sink attempting to gather information from a number of data sources. Figure 2 is a simple illustration of the difference between simple models of routing schemes that use data aggregation (which we term Data-Centric (DC)), and schemes that do not (which we term Address-Centric (AC)). They differ in the manner that the data is sent from a source to a sink. In the AC routing, each source independently sends data along the shortest path to the sink based on the route that the queries took (" end-to-end routing"), whereas in the DC routing the sources send data to the sink, but routing nodes on the way look at the content of the data and perform some form of aggregation and consolidation functions on the data originating at multiple sources.



(a) AC Routing (b) DC Routing

Figure 2. Illustration of AC routing Vs. DC routing

In ad hoc networks, a routing model follows the AC routing, so each source sends its information separately to the sink like the figure 1(a). In sensor networks, a routing model follows the DC routing, so the data from the two sources are aggregated at node A, and the combined data is sent from node A to the sink like the figure 1(b). Therefore in sensor networks, the data aggregation technique is a critical factor different from ad hoc networks to save the power consumptions of the nodes in order to extend the sensor network lifetime.

In sensor networks, the data aggregation tree can be thought of as the reverse of a multicast tree. So optimal data aggregation is a minimum Steiner tree on the network graph. Instead of an optimal data aggregation, sub-optimal data aggregations are proposed to generate data aggregation trees that are aimed to diminish the transmission power. The table 2 summarizes the properties and disadvantages of sub-optimal data aggregation methods.

The prevenient data aggregation methods [13] are efficient to the model where a single point in the unit square is defined as the location of an "event", and all nodes within a distance S (called the sensing range) of this event that are not sinks are considered to be data sources (which we term Event-Radius Model). In the model where some nodes that are not sinks are randomly selected to be sources, e.g. a temperature measurement and environment pollution detection (which we term Random-Source Model), it needs appropriate strategies for an efficient data aggregation.

Table 2. Comparisons of the data aggregation methods

Data aggregation method		Properties	Disadvantages
Optimal data aggregation method	Minimum Steiner Tree	The optimal number of transmissions required per datum for the DC protocol is equal to the number of edges in the minimum Steiner tree in the network.	The NP-completeness of the minimum Steiner problem on graphs

Sub-optimal data aggregation methods	CNS (Center at Nearest Source	The source that is nearest the sink acts as the aggregation point. All other sources send their data directly to this source that then sends the aggregated information on to the sink.	The more great the gaps between the aggregation point and sources, the more the batteries consumptions.
	SPT (Shortest Paths Tree)	Each source sends its information to the sink along the shortest path between the two. Where these paths overlap for different sources, they are combined to form the aggregation tree.	The shorter the overlapped paths when the shortest route is established from each source to the sink, the more the batteries consumptions.
	GIT (Greedy Increment-al Tree)	At the first step the tree consists of only the shortest path between the sink and the nearest source. At each step after that the next source closest to the current tree is connected to the tree.	It takes some time for the identical data to arrive to the aggregation point and to aggregate the identical data from other source nodes.

In LEACH, all of the nodes in the field can be the source nodes in sensor networks, so this model can be considered Random-Source Model. The nodes in LEACH organize themselves into local clusters, with one node acting as the cluster head, which allocates the time slot to its cluster members. All non-cluster head nodes directly transmit their data to the cluster head, while the cluster head node receives data from all the cluster members, performs signal processing functions on the data (e.g., data aggregation), and transmits data to the remote BS (Base Station). If the cluster heads were chosen a priori and fixed throughout the system lifetime, these nodes would quickly use up their limited energy because being a cluster head node is much more energy intensive than being a non-cluster head node. Thus LEACH incorporates randomized rotation of the high-energy cluster head position among the sensors to avoid draining the battery of any one sensor in the network. In this way, the energy load of being a cluster head is evenly distributed among the nodes. But LEACH needs clustering formation overheads before performing the task, and the nodes which are away from the cluster head consume much more transmission batteries comparing to the nodes close to the cluster head. So it needs a strategy to eliminate the redundancy power consume in LEACH.

2) Data aggregation in ad hoc networks

Most of the ad hoc networks are based on point-to-point communications, so the data aggregation in ad hoc networks is not considered a critical issue except the multipath routing. In some routing protocols such as DSR [14], AODV [15], LMR [16], TORA, and so on, multi-paths can be established from the sources to the destination. In that case the data aggregation can be performed through the overlapped paths en route. But it depends on each routing technique, which is implemented in ad hoc networks. Amongst the multipath routing techniques, TORA builds a directed acyclic graph rooted at the destination in ad hoc networks. So using DAG all data in the field can be assembled at the destination node.

2. The Analysis of Previous Routing Schemes in Broadband Convergence Networks

As the Internet and optical network technology advances, the IP over DWDM has been envisioned as the most promising solution for the next generation optical Internet. Especially, VPNs are well recognized as one of the critical applications of the future Internet market and have gained increased acceptance due to the economic benefits and maturing technology

[17-19]. Moreover, given the increasing demand for high bandwidth services, DWDM-based OVPN has been regarded as a favorable approach for the future VPN.

One of the critical issues in OVPN is Routing and Wavelength Assignment problem that is embossed as very important and plays a key role in improving the global efficiency for capacity utilization. In addition, many applications such as television broadcast, movie broadcasts from studios, video-conferencing, live auctions, interactive distance learning, and distributed games are becoming increasingly popular. These applications require point-to-multipoint connections among the nodes in the networks.

As a solution of such applications, multicast provides an efficient way of disseminating data from a source to a group of destinations, so the multicast problem in the optical networks has been studied for years and many efficient multicast routing protocols have been developed [20-23].

1) Source-rooted approach

In Source-rooted approach, a multicast tree is constructed with the source of a session as the root of the tree. The objective here is either to minimize total cost of the tree or to minimize individual cost of paths between the source and destinations. Depending on the objective there are two methods to construct a multicast tree (i.e. Source-based tree and Steiner-based tree) [3-4].

In Source-based tree generation methods [3], the destinations are added to the multicast tree in the shortest path to the source of a multicast session. These algorithms provide a computationally simple solution to the multicast tree generation, but have some limitations. Table 3 summarizes the properties, merits and demerits of each multicast tree generation method in the source-based tree approach.

Table 3. Comparisons of Source-based tree generation methods

	Re-route-to-Source	**Re-route-to-Any**	**Member-First**
Properties	Each destination finds its reverse shortest path heading for the source.	Each destination finds the nearest node in the current tree heading for the source.	The tree is constructed according to the link priorities, which was determined by whether or not the link is leading to destinations.
Advantages	Shortest delay, and simple implementation.	Moderate wavelength, channel resources, and delay required.	The least number of wavelengths and short delay.
Disadvantages	It requires the largest amount of channel resources and wavelength numbers.	The constructed tree may have some paths, which are not the shortest paths.	Computational complexity.

In Steiner-based tree [4], the destinations are added to the existing multicast tree one at a time in such a way that the total cost of the tree is minimized. To add a node to the tree, it is required to find the minimum cost path tree to all nodes in the tree. This approach is computationally expensive. Hence, heuristics are provided to choose a node to which the present node can be connected. Table 4 summarizes the properties, merits and demerits of each multicast tree generation method in the Steiner-based tree approach.

Table 4. Comparisons of Steiner-based tree generation methods

	Member-Only	**Capability-Based-Connection**	
Properties	It is similar to the Member-First method. However, if some intermediate nodes are located in equal distance from the present node, the node is connected to one of them selected arbitrary.	Spawn-from-VS heuristic	Capability-based-priority heuristic
		To spawn a new tree, each VS node acts like a source.	The Nodes in the networks are assigned with priorities depending on the wavelength conversion and splitting capabilities.
Advantages	It requires the least number of wavelengths and wavelength channel resources among all four algorithms (including this) already explained.	This approach needs less wavelength and channel resources compared to the Member-Only method.	
Disadvantages	Long delay, and computational complexity.		

For a given multicast session, the methods of the source-rooted approach construct a set of trees with an objective of either minimizing the total cost of the tree or minimizing the individual cost of the path between the source and the destinations. But the source-rooted approach has to consider all intermediate nodes that were laid in the paths between the source and the destination nodes in order to establish efficient path constructions. Therefore it has a long light tree setup time. In addition to the long setup time, the light tree needs to be reconstructed if the tree structure is changed or a link fails. For such a case, the Virtual Source-rooted approach was suggested.

2) Virtual Source-rooted approach

The algorithm based on this approach overcomes the limitations of the source-rooted approach. In the VS-based method, some nodes in the networks are chosen as VS nodes. Here VS nodes have splitting and wavelength conversion capabilities and can transmit an incoming message to any number of outgoing links on any wavelengths. These VS nodes are interconnected in such a way that a lightpath is established between every pair of VS nodes in order to reserve the resources, which can be used to transmit the message and to exchange the routing information for each multicast session request. These interconnectivities among the VS nodes are used when the multicast tree is constructed. Thus the multicast routing works in two phases, namely, a network-partitioning phase and a tree generation phase [5][24].

In the network-partitioning phase, nodes that have high degree of connectivity are chosen as VS nodes in about 20% of the given network's nodes, and the given physical networks are partitioned into several regions based on the vicinity of the VS nodes. A VS node can transmit an incoming message to any number of outgoing links. Therefore VS nodes act as a multicast session distribution point to the set of partitioned nodes that are connected to them. Once the VS nodes are identified, the paths between all VS nodes are computed. Every VS node establishes connections to all other VS nodes, and the remaining partitioned nodes in the networks grouped into sub-trees each with the root as a VS node.

In the tree generation phase, given a source and the set of destinations of a multicast session, the aim is to generate a multicast tree. This phase makes use of the connectivity provided in the previous phase. In order to provide multicast services, the source of a multicast session establishes a connection for the resource reservation to a VS node with the least distance from itself. Therefore, the source can establish the connections to all destinations using the connectivity provided in the previous phase. As a result, the setup time for establishing the multicast session becomes low.

Compared to the Source-rooted approach, this approach has some advantages. First of all, a source does not need to know about the location of the destinations, and there is a maximum of three light hop distance from a source to any destinations. Hence, the fairness among destinations is achieved. And the procedure of dynamic addition or deletion of members in the group is simple in comparison with the Source-rooted approach. Whereas the VS-based tree method has a critical default such like that as the number of VS nodes increases, the overheads due to the resource reservation for paths between VS nodes also increase. Such overheads affect the network performances in the networks that the resources are limited.

3) MW-MIPR approach

In the VS-based method, it requires shortest paths between VS nodes because each multicast session needs to reserve the resources for paths between VS nodes. Therefore the blocking probability of potential future multicast session requests increases due to the frequently used shortest paths, especially the paths between VS nodes.

In order to overcome such a limitation, it needs a strategy to control the traffics of paths between VS nodes. That is because the paths between VS nodes should be critical paths due to the shortest path selection to make each multicast session request. As a strategy, we can reduce the use of those paths choosing efficient paths, instead of the shortest path; so decrease the utilization of wavelength number throughout the networks.

As a solution of traffic control, we investigated the previously proposed Minimum Interference Routing algorithm with traffic engineering in a Multi-Protocol Label Switching network [6-9]. The key idea of MIR is to pick a path that does not interfere too much with potential future setup requests between some source-destinations pairs. In [7], Multi-Wavelength Minimum Interference Path Routing (MW-MIPR) was proposed for an extension of MIR. This method suggested an important role in enhancing the resource utilization and in reducing the overall call blocking probability of the networks through efficiently utilizing wavelengths by taking into consideration the potential future network's congestion states. As a result, using the term, i.e., critical link [6], this algorithm chooses a light path that does minimize interference for potential future setup requests by avoiding congested links. We adopt the concept "critical link" to reduce the utilization of the frequently used paths in each path between every two VS nodes.

Ⅲ. The DAUCH Data Aggregation Algorithm in Ubiquitious Sensor Netwroks

1. Definition of DAUCH

The new data aggregation algorithm is illustrated by the figure 3. Each cluster head that is elected randomly creates the DAG rooted at the cluster head. The nodes that have more than one uplink node aggregate the data arrived from the uplink nodes then transmit them to the downlink node. This manner is continued until all data arrive at the cluster head. The cluster heads receive and aggregate the data from the adjacent neighboring node, and then transmit them to BS.

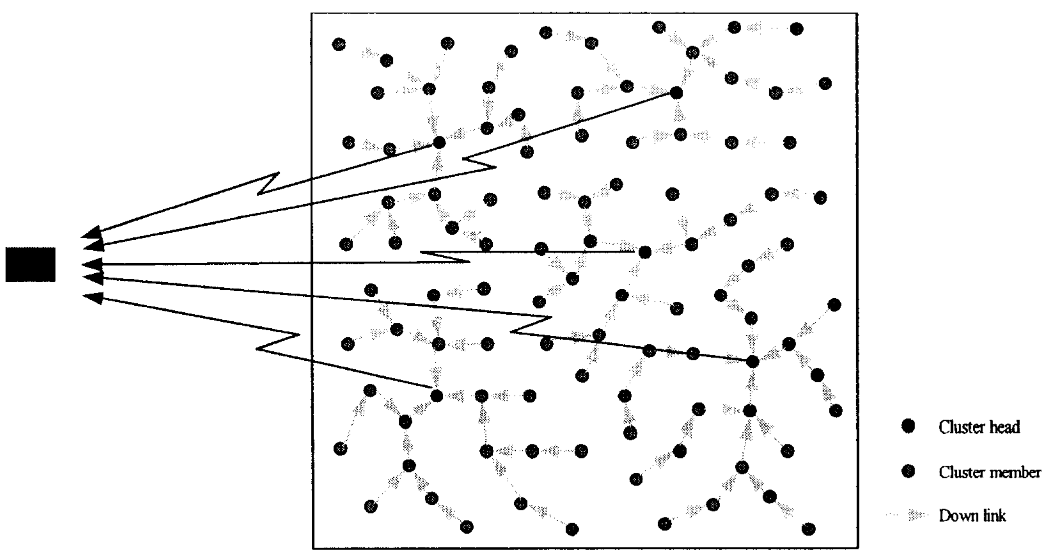


Figure 3. Illustration of the new data aggregation algorithm

2. The properties of DAUCH

In DAUCH, each cluster head that is elected randomly in the field creates a DAG centered at itself. Using DAG DAUCH creates the more effective cluster comparing to LEACH, and the nodes that are away from their cluster head save the data transmission power consumption using multi hop transmissions because of the shorter radio propagation distance. Moreover before the whole data get to the cluster head, some data aggregations are performed in the overlapped routes, so the task effort of data aggregations of the cluster head is distributed to other nodes that are not a cluster head.

But it is only effective supposed that all of the nodes are evenly distributed in the sensor field. Moreover there is a time delay in the case that the data of the nodes that are away from the cluster head arrive at the cluster head, and some overhead in the case that the links that connect the uplink with the downlink are unstable because of the dynamic movement of some nodes.

For the development of DAUCH, we made some assumptions about the sensor nodes and the underlying network model. For the sensor nodes, we assume that all nodes can transmit with enough power to reach the BS if need, that each node has the computational power to perform signal processing functions, and that all nodes are synchronized by each other in a sensor field. These assumptions are reasonable due to technological advances in radio hardware, low-power computing, and time synchronization techniques. For the network, we use a model where nodes always have data to send to the end user, nodes located close to each other have correlated data, all sensor nodes are evenly distributed and quasi static, and the message from the sender is correctly accepted by the receiver. Although DAUCH is optimized for this situation, it will continue to work if it were not true.

3. Requirements

The new algorithm uses five types of messages to communication.

- DAG construction packet – when the cluster head creates DAG rooted at itself, the cluster head generates the DAG construction packet and broadcast the packet to the adjacent neighboring nodes. It contains the information of Cluster_Head_ID and Downlink_Node_ID, where Cluster _Head _ID is the current cluster head's ID and Downlink_Node_ID is the node that transmits the current DAG construction packet, and each DAG construction packet contains a cluster radius and a height. The former indicates the node hop number that is the farthest node of a cluster, and the latter express the hop number how far the current node is apart from the cluster head, respectively.
- DAG deconstruction packet – when each round is ended, the cluster head generates a DAG deconstruction packet and sends it to all the cluster members in order to inform them of the end of a current round and the beginning of a new round. It contains Cluster_Head_ID and a cluster radius, and they inform the current cluster head's ID and the node hop number that is the farthest node of a cluster, respectively.
- ACK packet – when a link breakage occurs, an uplink node sets a downlink flag and sends ACK packet to a downlink node whose

height is the same as or less than itself in order to reconstruct the broken link. The ACK packet contains Cluster_Head_ID and Transmitter_ID. Herein Transmitter_ID presents the node ID that sends the ACK packet.

- Non_ACK packet – when a node receives more than one message from its neighboring nodes and then collision occurs, it sends the packet to its neighboring node to retransmit. The Non_ACK packet contains Cluster_Head_ID and Transmitter_ID.
- DATA packet – the nodes that have the data to send it to the cluster head use DATA packet to transmit the data. DATA packet is sent to the downlink node and on the way the packet is aggregated by the nodes that have more than one neighboring node. Finally all the data of a cluster are aggregated by the cluster head and sent to BS. The data packet contains Source_ID, Cluster_Head_ID, Transmitter_ID, and Data. Herein Source_ID presents the node that senses the event in a sensor field.

Each node caches the adjacent neighboring node IDs and stores their heights as well.

4. The operation of DAUCH

The operation of DAUCH is divided into rounds and each round consists of five phases logically.

1) Cluster head selection phase

DAUCH's cluster heads are stochastically selected like LEACH. In order to select cluster heads, each node n determines a random number between 0 and 1. If the number is less than a threshold $T(n)$, the node becomes a cluster head for the current round. The threshold is set as follows:

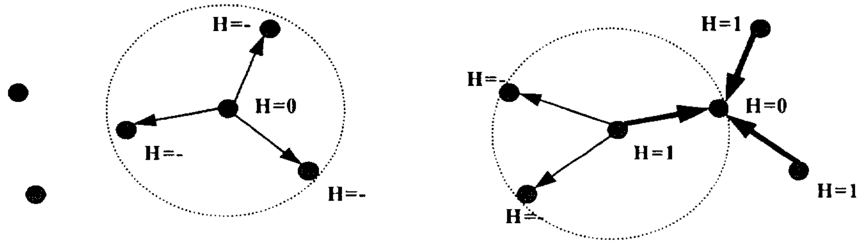
$$T(n) = \frac{P}{1 - P(r \bmod \frac{1}{P})} \qquad \forall n \in G \qquad (1)$$

$$T(n) = 0 \qquad \forall n \notin G \qquad (2)$$

with P as the cluster head probability, r as the number of the current round, and G as the set of nodes that have not been cluster head in the last $1/P$ round. This algorithm ensures that every node becomes a cluster head exactly once within $1/P$ rounds.

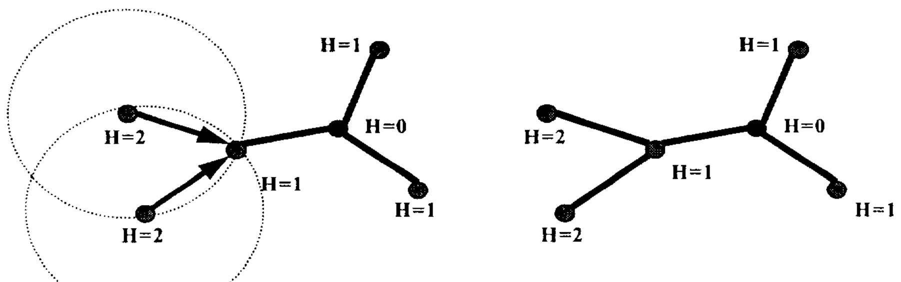
2) DAG construction phase

After the cluster head selection phase, the cluster heads of each cluster broadcast the DAG construction packet to the neighboring nodes, as shown in figure 4(a). The nodes that receive the DAG construction packet set their heights that present the hop number how far the current node is apart from the cluster head, and then rebroadcast the packet to the neighboring nodes (figure 4(b)). If a node receives more than one DAG construction packet, it takes the message whose hop count is smaller than the others, and the messages that do not be taken are discarded. This manner is continued until the hop counter of the DAG construction packet reaches a cluster radius. After all, each cluster constructs DAG rooted at its cluster head.



(a) The cluster head broadcasts the DAG construction packet to the neighboring nodes.

(b) The nodes that receive DAG construction packet set their height and then rebroadcast the packet.



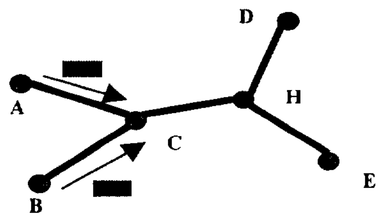
(c) Using DAG construction packet, each node establishes the downlink rooted at the cluster head.

(d) Each cluster constructs DAG rooted at the cluster head.

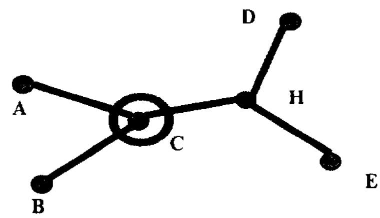
Figure 4. The procedure of DAG construction

3) DATA transfer phase

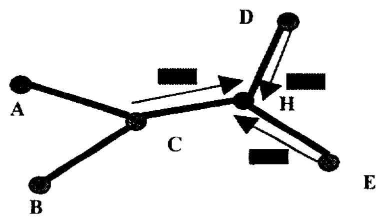
After a DAG construction is completed, the nodes that are farthest from the cluster head send the data to the neighboring downlink node, as shown in figure 5(a). After receiving the data, the node aggregates the data with own data, and then sends the aggregated data to the neighboring downlink node (figure 5(b), (c)). After all, every data within a cluster is assembled and aggregated at the cluster head, and then it is sent to BS, as shown in figure 5(d).



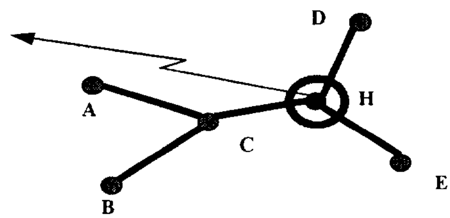
(a) Node A, B send DATA packet to the neighboring downlink node.



(b) Node C aggregates DATA packet arrived from node A and B with its own data



(c) Every data within a cluster is assembled at the cluster head.



(d) After aggregating the data, the cluster head sends the aggregated data to BS.

Figure 5. The procedure of DATA transfer

4) Downlink failure phase

When a node's link that connects the neighboring two nodes is broken due to the node's movement or complete battery consumption, the uplink node sends ACK packet to reconnect a downlink path with the node which height is the same as or less than a previous downlink node with setting downlink flag. If there doesn't exist the node which height is the same as or less than a previous downlink node, or there isn't any respond to the ACK packet within TTL, the node directly sends its data message to the cluster head.

5) DAG deconstruction phase

Before the end of each round, the current cluster heads generate DAG deconstruction packets and send them to all the cluster members in order to inform the cluster members of the end of a current round and the beginning of a new round. And the packet is delivered until the nodes located in the end of the cluster, i.e. cluster radius.

Ⅳ. VS-MIPMR Algorithm in Broadband Convergence Networks

1. VS-MIPMR Definition and Notations

The illustrated OVPN reference architecture in figure 6 consists of the customer sites (i.e. OVPN A and OVPN B) in the electric control domain and the DWDM-based backbone network in the optical domain. The external VPN aggregates IP packets, which have the same destined packets at the Client Edge (CE) nodes to reduce network complexity and to make operation simple. The internal OVPN backbone network consists of the Provider Edge (PE) nodes (i.e., Source nodes and Destination nodes) and the Provider Core (PC) nodes (i.e., Virtual Source nodes and Neighboring nodes) and these elements forward data traffic between VPNs without electric-optic-electric conversions [19]. In OVPN, the goal is to establish several OVPN connections on the physical topology, which provide a variety of multicast services and need to make resource reservations in order to construct light trees of the corresponding multicast services.

In the VS-based tree method, as the number of VS nodes increases, the overheads due to the resource reservations for paths between VS nodes also increase, where the resources are needed to exchange the information for each sub-tree when the VS-based tree method constructs the multicast trees among the VS nodes. Moreover many potential future multicast session requests may make the paths between VS nodes busy because they need additive resource reservations and use critical links so that the networks can waste redundant wavelength numbers. So it needs a suitable strategy to follow efficient paths between VS nodes that avoid the critical paths.

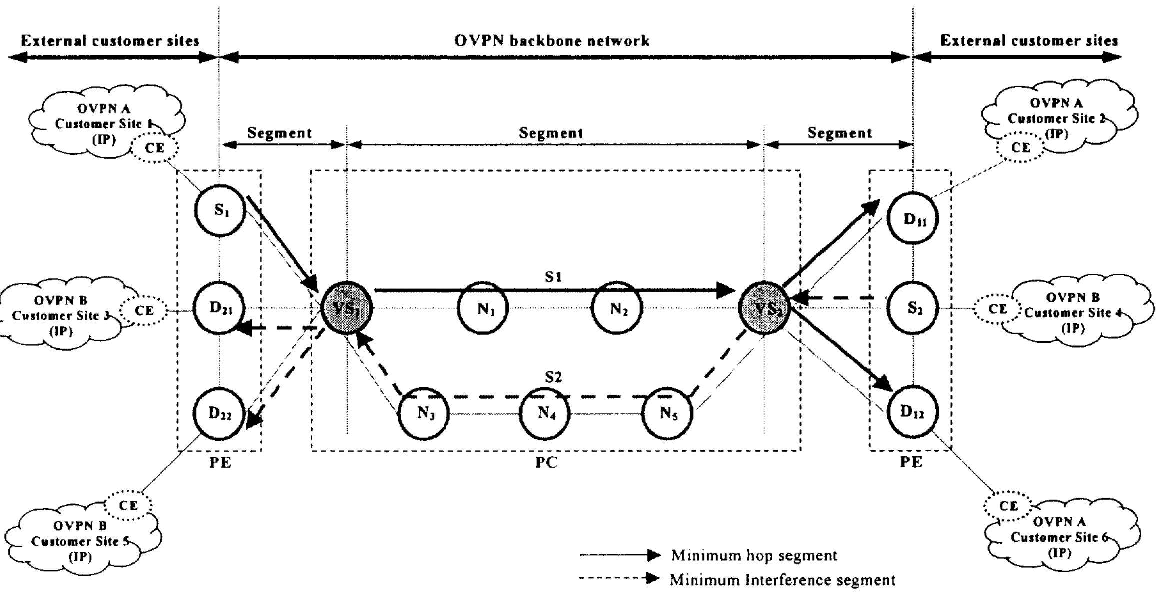


Figure 6. Illustration of a new MCRWA algorithm in DWDM-based OVPN

In this paper, we propose a new Multicast Routing and Wavelength Assignment method choosing a path that does not interfere too much with potential future multicast session reservation requests based on VS-rooted approach, called Virtual Source-based Minimum Interference Path Multicast Routing [6-10]. Choosing efficient paths considering the potential future network's congestion states instead of the shortest path, the new algorithm overcomes the limitation of the VS-based method and provides the efficient utilization of wavelengths.

Figure 6 illustrates the new algorithm. We assume that Segment means a path between a source (or a destination) and the nearest VS node or between VS nodes, and each segment must follow the wavelength continuity constraint [25-26], because only VS node can have a wavelength conversion capability.

There are two potential source-destinations pairs such as (S_1, D_{11} & D_{12}) and (S_2, D_{21} & D_{22}). When S1 is chosen for the first multicast session in order to make a resource reservation for the path between VS_1 and VS_2, the other multicast session may share the same path having a minimum-hop path but can lead to high blocking probability by inefficiently using the resource due to the traffic concentration on that path. Thus, it is better to pick S2 that has a minimum interference effect for other future multicast session requests, even though the path is longer than S1. Before formulation of the new algorithm, we define some notations commonly used in this algorithm as follow:

- $G(N,L,W)$: The given network, where N is the set of nodes, L is the set of links, and W is the set of wavelengths per link. In this graph, the number of wavelengths per link is same for each link belonging to L.
- (v_i, v_j) : A VS-nodes pair.
- (a,b): A VS-nodes pair to require the resource reservation for a multicast session when constructing a multicast tree ($(a,b) \in (v_i, v_j)$).
- M : The set of potential source-destinations pairs that can request resource reservations for multicast sessions in the future.

- S_{ij}^n : The set of minimum hop segments connecting the path between (v_i, v_j) pair. (n=1,2,3)
- α_{ij} : The weight for each segment between the VS-nodes.
- C_{ij} : The set of critical paths between (v_i, v_j) pair.
- Δ : A threshold value of the available wavelengths on S_{ij}^n (30% of the total wavelengths in S_{ij}^n).
- F_{ij}^n : The number of available wavelengths in S_{ij}^n .
- $\frac{\partial F_{ij}^n}{\partial v}$: The interference weight to reflect the change rate of available wavelengths in S_{ij}^n .
- $R(S_{ij}^n)$: The accumulated total weights for S_{ij}^n .

Among the notations, α_{ij} and C_{ij} are key parameters in VS-MIPMR. Here α_{ij} statistical ly presents the weight for a segment according to the degree of multicast session resource reservation requests between the VS-nodes, and C_{ij} indicates bottleneck links between the VS-nodes, which are shared on the minimum hop paths of other node pairs at the same time.

2. Procedure of VS-MIPMR

Based on these notations, the link weights are determined as follow:

$$Max \sum \alpha_{ij} \cdot F_{ij}^{\ n} \tag{3}$$

$$
\left(
\begin{array}{c}
\dfrac{\partial F_{ij}^{n}}{\partial v} = 1 \\
if\,(v_i, v_j) : \{S_{ij}^{n} \in C_{ij}\} \cap \{F_{ij}^{n} < \Delta\} \\
\dfrac{\partial F_{ij}^{n}}{\partial v} = 0.5 \\
if\,(v_i, v_j) : \{S_{ij}^{n} \in C_{ij}\} \cap \{F_{ij}^{n} > \Delta\} \\
\dfrac{\partial F_{ij}^{n}}{\partial v} = 0, \quad otherwise
\end{array}
\right) \tag{4}
$$

$$
R(S_{ij}^{n}) = \sum_{\forall (v_i, v_j) \in M \setminus (a,b)} \alpha_{ij} \cdot (\partial F_{ij}^{n} / \partial v) \tag{5}
$$

Equation (3) presents the minimum interference of the wavelength path decision between the VS-nodes in order to choose the optimal path according to the present multicast session request. Equation (4) allocates the differentiated values to the *n*th segment between VS nodes which were determined by the previous multicast session requests and the available wavelengths, according to the interference weight of segments that have a minimum-hop number path requested by the previous multicast session requests. As shown in equation (4), if the present path interferes with the previous light path and F_{ij}^{n} is smaller than Δ of available wavelengths, it is equal to 1. If the present path interferes with the previous light path and F_{ij}^{n} are larger than Δ of available wavelength, then it is equal to 1/2. If there is no interference with the previous light path, then it is equal to 0 when allocating the wavelengths according to the present request. Equation (5) presents the summation of the differentiated values to the *n*th segment according to the given multicast session request. Therefore the algorithm decides a light path that has a minimum value of segment weight $R(S_{ij}^{n})$. Figure 7 illustrates such a procedure of VS-MIPMR.

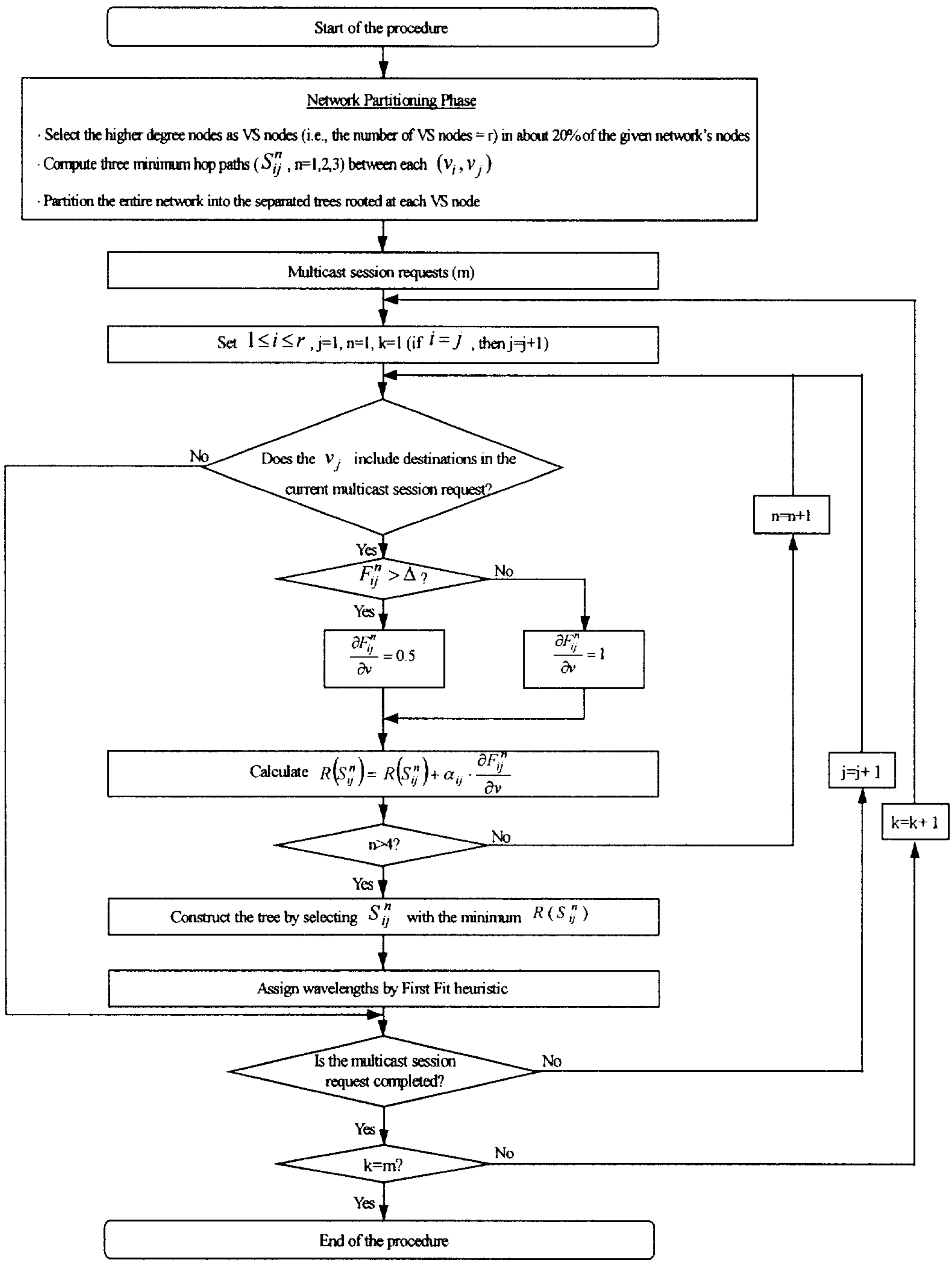


Figure 7. Procedure of VS-MIPMR

Ⅴ. Analysis and Simulation Results

1. The Analysis and Simulation Results for DAUCH

1) Radio energy dissipation model for DAUCH

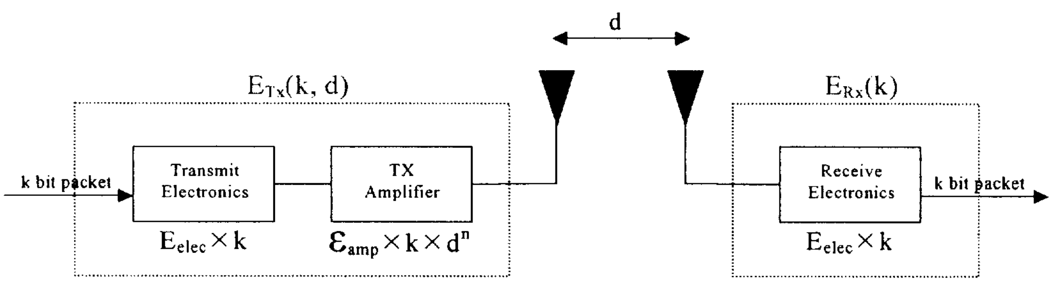


Figure 8. Radio energy dissipation model

For our experiment, we used a 100-node network where nodes were randomly distributed between ($x = 0m, y = 0m$) and ($x = 200m, y = 200m$) with BS at location ($x = 100m, y = 300m$). We assume a simple model [11] for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics ($E_{Tx-elec}$) and the power amplifier (E_{Tx-amp}), and the receiver dissipates energy to run the radio electronics ($E_{Rx-elec}$), as shown in figure 8. Therefore the radio energy dissipations of the transmitter and the receiver are set as follow:

Transmitting:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$$
$$E_{Tx}(k,d) = E_{elec} \times k + \varepsilon_{amp} \times k \times d^{n} \quad (6)$$

Receiving:

$$E_{Rx}(k) = E_{Rx-elec}(k)$$
$$E_{Rx}(k) = E_{elec} \times k \quad (7)$$

where d is a distance from a transmitter to a receiver, k is k-bit messages, and n is an exponential factor depending on the distance between the transmitter and the receiver. In the free space channel model, n is set to 2, and in the multipath fading channel model, n is set to 4 [27]. In our model, the distance between each cluster member and a cluster head is set to the free space channel model, and the distance between cluster heads and BS is set to the multipath fading channel model.

2) Analysis of the radio energy dissipation model

In order to analyze the different radio energy dissipation of LEACH and DAUCH, we apply the equation (6) and (7) to radio energy dissipation model for the data transmission and reception. Figure 9 presents the different data transfer model of LEACH and DAUCH. The inner and outer circles are implemented to easily compute the radio energy dissipation quantities based on the distance between each cluster member and a cluster head. We set the radius of the inner circle to d, and the radius of the outer circle to $2d$.

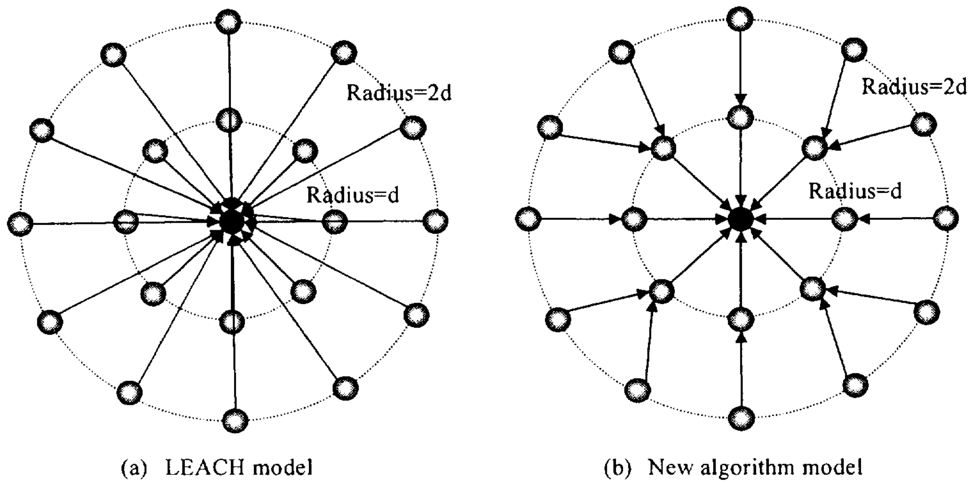


Figure 9. Comparison LEACH model with the new algorithm model

In LEACH, the radio energy dissipations for the data transmission and reception can be computed using the figure 9(a). The energy dissipation of the inner nodes is set as follows:

$$8[E_{elec} \times k + \varepsilon_{amp} \times k \times d^2 + E_{elec} \times k] \quad (8)$$

, the energy dissipation of the outer nodes is set as follows:

$$12[E_{elec} \times k + \varepsilon_{amp} \times k \times (2d)^2 + E_{elec} \times k] \quad (9)$$

, and the total energy dissipation of the nodes is set as follows:

$$20[E_{elec} \times k] + 56[\varepsilon_{amp} \times k \times d^2] + 20[E_{elec} \times k] \quad (10)$$

In the new algorithm, the radio energy dissipations for the data transmission and reception can be computed using the figure 9(b). The energy dissipation of the inner nodes is set as follows:

$$8[E_{elec} \times k + \varepsilon_{amp} \times k \times d^2 + E_{elec} \times k] \tag{11}$$

, the energy dissipation of the outer nodes is set as follows:

$$12[E_{elec} \times k + \varepsilon_{amp} \times k \times d^2 + E_{elec} \times k] \tag{12}$$

, and the total energy dissipation of the nodes is set as follows:

$$20[E_{elec} \times k] + 20[\varepsilon_{amp} \times k \times d^2] + 20[E_{elec} \times k] \tag{13}$$

assuming that the total power consumption of the data aggregation is much smaller than the energy dissipation of the data transmission and reception, with comparing equation (10) with equation (13), we conclude that the new algorithm is superior to LEACH with regard to the radio energy dissipations for the data transmission and reception.

3) Simulation results

For the presented simulations we use C++ programming. Each node is equipped with an energy source whose total amount of energy accounts for 2J(Joule) at the beginning of the simulation. Every node transmits a 500 bytes message. The cluster head probability P is set to 0.05 [11].

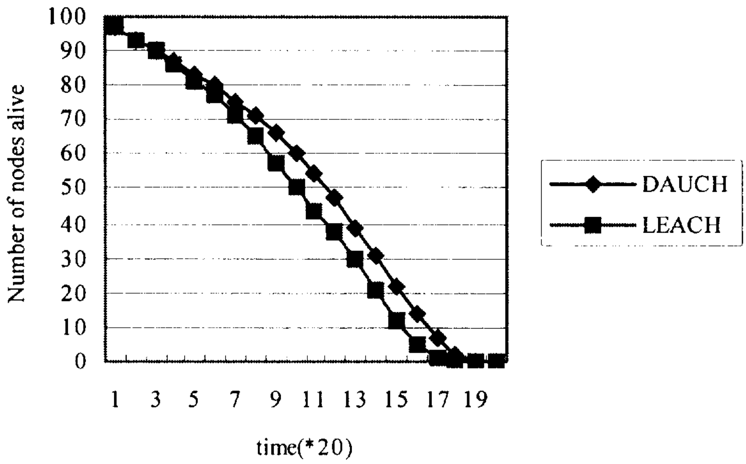


Figure 10. Number of nodes alive over time

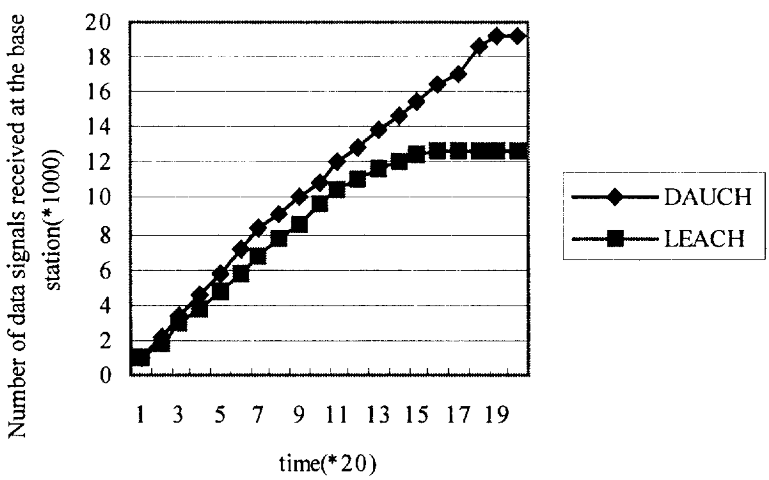


Figure 11. Number of data signals received at the base station over time

Figure 10 and 11 illustrate simulation results of our sample network. According to our simulation results, the proposed method improves approximately 4% comparing to the number of nodes alive with LEACH. This is due that the new data aggregation uses smaller energy dissipation of the data transmission and reception than LEACH. Therefore the total amount of the new data aggregation algorithm's data received at the BS over time is better than that of LEACH due to the extended sensor network life time.

2. The Analysis and Simulation Results for VS-MIPMR

In this section, simulation studies are carried out to evaluate the performance of VS-MIPMR. The simulation is run on Pentium 4 PC with 2.8GHz CPU and 512MB RAM. The network models used in the simulations are 14-node and 24-node topologies, as shown in figure 12, that are currently often used as DWDM network models and adopted in most of the papers related to DWDM networks. And we assume that the multicast session requests arrive randomly according to the Poisson process.

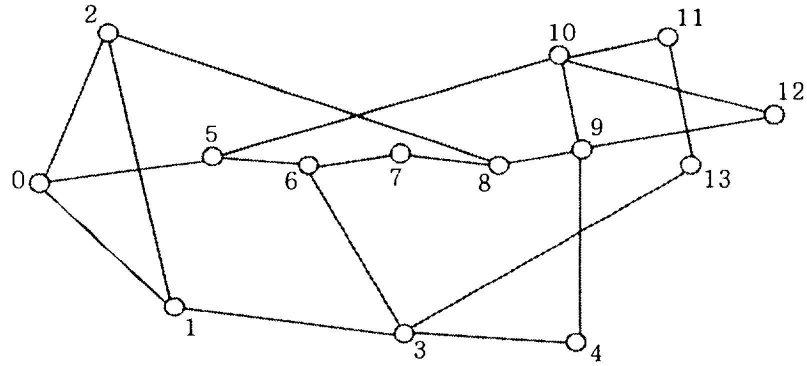
We will compare the results of our algorithm with VS-based method in respect of the utilization of the wavelength numbers and the wavelength channel numbers, and analyze the gain of the wavelength numbers and the loss of the wavelength channel numbers. Here the gain and the loss mean the differences of the wavelength numbers and of the wavelength channel numbers between our algorithm and Virtual Source-based method, respectively.

In order to prove the efficiency of VS-MIPMR algorithm proposed in section 4, we showed the wavelength numbers and the wavelength channel numbers of VS-MIPMR and the Virtual Source-based method; here the Group Size (GS) that determines the number of members to construct a multicast session is 0.3 and 0.4 [24]. Figure 13 reveals that the proposed VS-MIPMR algorithm outperforms the Virtual Source-based method due to the selection of the minimum interference paths. Therefore VS-MIPMR can accomplish approximately 24% and 25% improvements of the wavelength numbers in case of GS 0.3 of 14-node and 24-

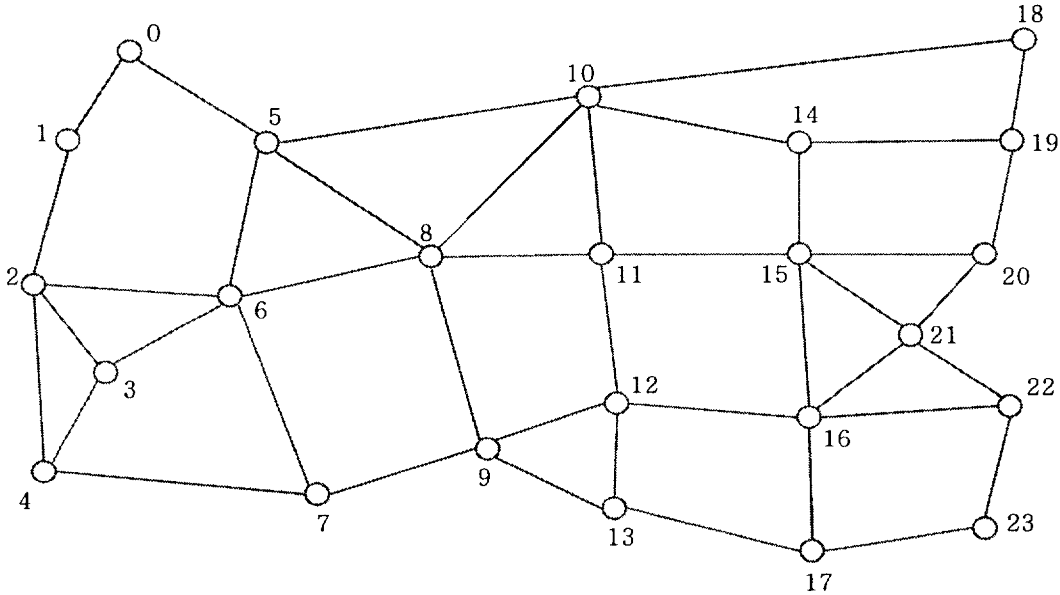
node topologies, respectively, in comparison with those of the VS-based multicast method, when the seventh multicast session arrived. And in case of GS 0.4, the gain is more improved in 24-node topology than in 14-node topology. Therefore we identify that our algorithm can be performed more efficiently in the extended networks, as shown in figure 14.

Although VS-MIPMR needs slightly more numbers of wavelength channels than those of Virtual Source-based method due to the detour paths to avoid congestion links shown in figure 15, we can identify that the loss of the wavelength channel does not exceed 7% and 2% in 14-node and 24-node topologies, respectively, as shown in figure 16.

In conclusion, using VS-MIPMR we can construct the multicast trees more efficiently than the Virtual Source-based method, even though we experience a bit of loss in the wavelength channel numbers.

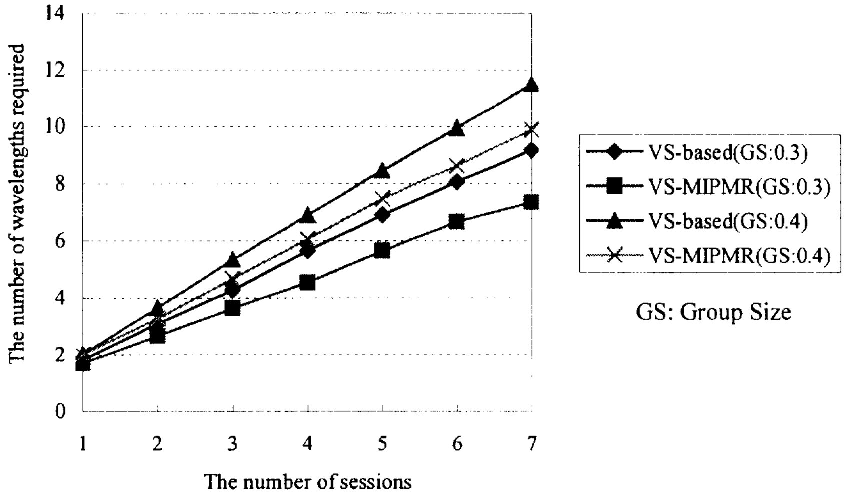


(a) 14-node topology

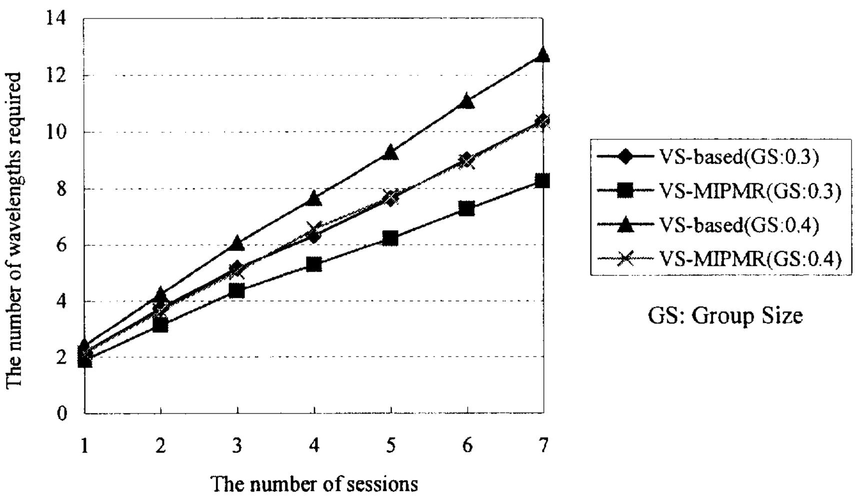


(b) 24-node topology

Figure 12. Example network topologies

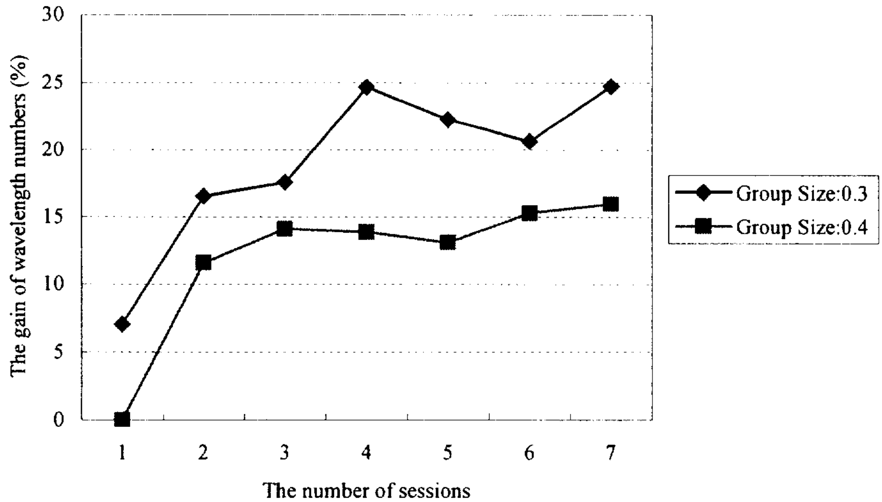


(a) 14-node topology

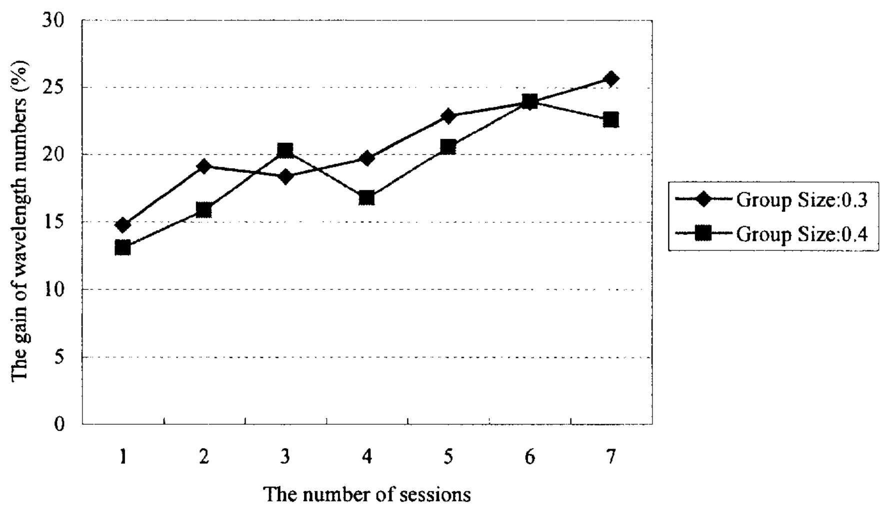


(b) 24-node topology

Figure 13. The number of wavelengths over sessions

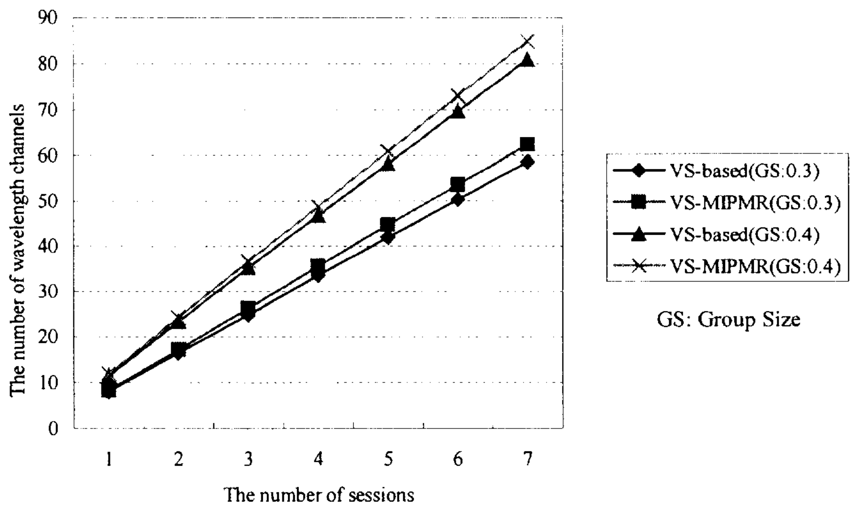


(a) 14-node topology

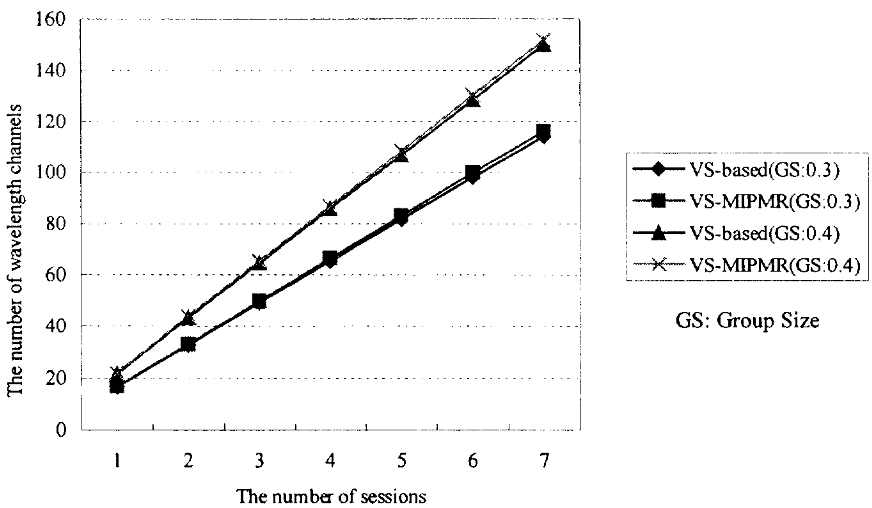


(b) 24-node topology

Figure 14. The gain of wavelength numbers over sessions

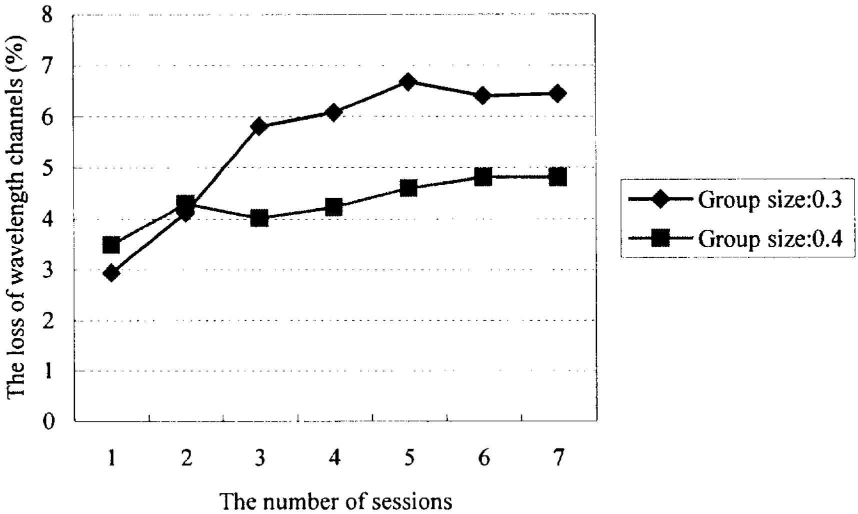


(a) 14-node topology

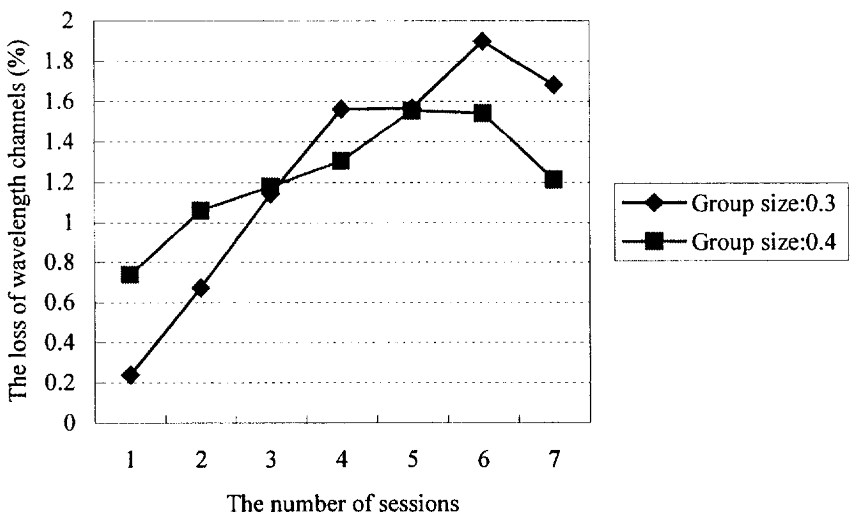


(b) 24-node topology

Figure 15. The number of wavelength channels over sessions



(a) 14-node topology



(b) 24-node topology

Figure 16. The loss of wavelength channel numbers over sessions

VI. Conclusion

This paper proposed a new data aggregation algorithm for clustering distributed nodes in ubiquitous sensor networks, combining the random cluster head election technique in LEACH with DAG which constructs an efficient cluster in TORA. The proposed data aggregation algorithm outperforms LEACH by diminishing the radio energy dissipations for the data transmission and reception, and extending sensor network lifetime in comparison with LEACH.

In addition to the new data aggregation algorithm in USNs, we also proposed a new Multicast Routing and Wavelength Assignment algorithm in DWDM-based OVPN. According to our simulation results, even though VS-MIPMR needs slightly more numbers of wavelength channels (e.g., 7% and 2% in 14-node and 24-node topologies, respectively) due to the detour paths to avoid congestion links, our algorithm significantly improves the utilization of wavelength numbers over sessions (approximately 24~25% in our network topologies), comparing with the Virtual Source-based method in DWDM-based OVPN.

The proposed multicast routing algorithm could be applied to the GMPLS (Generalized Multi-protocol Label Switching) call control protocol in DWDM-based OVPN.

As a future research, we have a plan to apply the proposed algorithm to the various network models that have more nodes than ours, and conduct simulations to verify the efficiency of the algorithm. In addition to verifying the efficiency, we will expand the new algorithm for differentiated multicast applications in a variety of QoP (Quality of Protection)-based service classes in the next generation Optical Virtual Private Networks.

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Ubiquitous 및 Broadband Convergence Networks 환경에서의 Routing 알고리즘 연구

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요 약

지난 수 십 년간 통신 기술의 급속한 발전은 인터넷 및 voice telephony, video conferencing, tele-immersive virtual reality, and Internet game 등과 같은 실시간 멀티미디어 서비스의 급격한 발전을 가져왔다. 이에 따라 다양한 서비스를 통합하여 전송하기 위한 연구가 계속해서 이뤄져 왔으며, 특히 우리나라의 경우 통신, 방송, 인터넷이 융합된 광대역통합망 (Broadband Convergence Network)을 활성화시키기 위한 움직임이 여러 서비스 제공업자들에 의해서 지속적으로 연구되어왔다.

BcN 이란 통신, 방송, 인터넷이 융합된 품질보장형 광대역 멀티미디어 서비스를 언제 어디서나 끊김 없이 안전하게 이용할 수 있는 차세대 통합 네트워크를 말한다. 이러한 네트워크를 지원해 주기 위해서 차세대 통합망은 하나의 파이버에 여러 파장을 다중화하여 많은 양의 정보를 전송할 수 있는 DWDM 기반의 광전송망의 구비가 필수적이다. 한편 전광망을 제어하기 위한 목적으로 GMPLS 가 현재 IETF 에서 표준화가 진행중이다. 따라서 IP/GMPLS over DWDM 망이 차세대 통합 네트워크에 사용될 주요 기술로 떠오르고 있다.

차세대 통합 네트워크에서 다양한 멀티미디어 서비스를 제공하기 위해서

기존의 유니캐스트 방식이 아닌 멀티캐스트 라우팅 방식이 대역폭 활용측면에서 좀더 효율적인 해결책을 제공한다. 이에 본 논문은 차세대 통합 네트워크의 백본망 계층을 제어하는 IP/GMPLS over DWDM 망에서 멀티캐스트 서비스를 지원하기 위한 멀티캐스트 라우팅 알고리즘을 제안한다.

DWDM 기반의 백본망의 효율적인 제어와 더불어 응용분야에 따라 다양하게 제어되는 외부 망에 대한 적절한 제어 알고리즘의 구비 또한 중요하며, 그 중 특히 유비쿼터스 센서 네트워크는 언제 어디서든 얻고자 하는 정보에 대한 적절한 해결책을 제시한다. 이러한 유비쿼터스 센서 네트워크에서는 망 전체의 생존시간을 증가시키기 위해서 각 노드의 효율적인 에너지 사용이 필수적이다. 이에 본 논문은 유비쿼터스 센서 네트워크에서 각 노드의 전력 사용을 줄이기 위한 방안으로 새로운 데이터 통합 알고리즘 또한 제안하다.

본 논문은 유비쿼터스 센서 네트워크에서 효율적인 에너지 사용에 필요한 데이터 통합 알고리즘을 포함하여 통합된 다양한 멀티미디어 서비스를 제공하기 위한 BcN 기반의 멀티캐스트 라우팅 알고리즘을 제시하여, 향후 제공될 차세대 통합 네트워크의 전반적인 해결책을 제시한다.

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