# Research on Innovating, Evaluating and Applying Multicast Routing Technique for Routing Messages in Service-Oriented Routing

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**Abstract.** MANET (short for Mobile Ad-Hoc Network) consists of a set of mobile network nodes, network configuration changes very fast. Each node will act as a router to maintain network operation. There is no central node for controlling entire network. So routing in MANET is very important.

In content based routing, data is transferred from source node to requested nodes is not based on destinations addresses. Therefore it is very flexible and reliable, because source node does not need to know destination nodes. As some standard content based routing protocols, when a node publishes its content, It will broadcast data to network. The published content will be cached at all routes on the network. So when a node publish a request to get some content, it will prepare a subscription message then broadcast it to network. When any node on network received that subscription, it matches subscriptions content with published content that have been cached on it. If found then matched content will be transferred to requested node. There is another routing model when nodes have content requests, they broadcast subscription messages to network. When nodes receive subscriptions, they cache these messages. When a node publish its content by broadcast protocol, any node receives that content, it will match received content with subscriptions cached on it to find all nodes have requested that content, then forwarding that content to these nodes.

Service Oriented Routing is inherited from the model of content based routing (CBR) [3, 4], combined with several advanced techniques such as Multicast increase the data rate [6], and data encryption to ensure information security.

This article presents some techniques to support multicast packet forwarding from one network node to a set of nodes with guaranteed quality

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of service. By using these techniques can decrease network load, congestion, use network resources efficiently.

**Keywords:** Ad hoc network, MANET, QoS, bandwidth guarantee, time slot assignment, routing, service, content.

## 1 Introduction

Publish/Subscription Model (abbreviated P/S) is the interaction model is performed asynchronously in the content based routing systems [3].

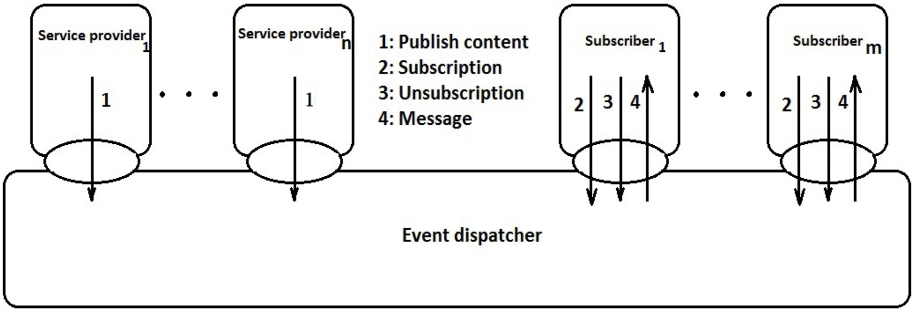


**Fig. 1.** Service based routing model

Each network node must undertake the following roles: service provider, content receiver, router. To perform these tasks efficiently at each node of the network We have to install a specific routing protocol. Currently there are many routing protocols developed for MANET such as OLSR, CBR, DSR, DSDV, AODV, ODMRP, in which there are some content based protocols. In the article We will make use of the advantages of these routing protocols and customize some important characteristics to construct novel routing protocol that is oriented service and guarantees quality of service, for example bandwidth and latency, failover, etc.

Service oriented architecture allows flexible communication, the ability to provide location transparency for the transmission of information between applications. Position transparency is defined as the connection to avoid the point - to - point because the application is separated with the data transmission services below, will undertake the implementation when the applications require communicating with each other.

Service-based network infrastructure is a new network interface in which the flow of messages is controlled by class of service that generated it. Next is its content, improved shipping address specified by the sender and attached to the message. Networks based on services complement for networks based on traditional unicast and multicast addresses, which provides support for communication patterns based on the service class of large-scale applications, loose connections, multiple partitions and scattered like auctions, information sharing, combined, distributed, sensor networks, distributed according to personal information, service discovery, multi-player game.

In the SBR routing, the sender does not indicate message receiver by the unicast or multicast use. Instead it simply pushes messages to the network. It defines the routing based on the messages it cares. It determines the appropriate message class based on message content based on its key-value pairs or regular expressions. Therefore, in SBR routing the receiver determines the transmission of messages, not the sender. Communication based on content services increases the independence, flexibility in the distributed architecture.

## 2 Organization of Types of Messages in SBR Network

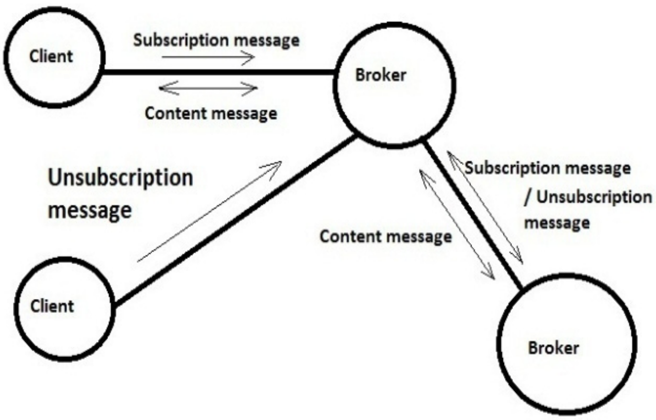


**Fig. 2.** Message transmission model in service-oriented routing network

### 2.1 Introduction of Message Types [3,4,6]

In order to perform service based routing, We have to organize data into messages, there are some message types will been constructed. That are:

**Subcription/Unsubcription Message.** Use this message type to register/unregister nodes requested content.

**Content Message.** Use this message type to publish nodes content.

**Advertisement Message.** Use this message type in order to advertise nodes content, to direct subscriptions from subscribers to matched publishers, avoid to flood subscriptions all over networks. When a node need to advertise its content: i) Make an advertisement message; ii) It will broadcast this content advertisement message to network. iii) Its content advertisement will be cached on nodes of network. When a subscription message happen on a node: a) Firstly It check that if subscription is matched with its published content. If it is true matched content will be sent to requested node immediately. b) Secondly, it will be matched with content advertisements on that node. Then this subscription will be transmitted to a set of matched advertisement nodes. So that We have to build multicast tree from requested node to the set of matched advertisement nodes to decrease latency and bandwidth required.

**Update Request and Reply Sender Message Pair.** In order to update routing table of content based routing protocol. By using minimum spanning tree (established by PRIM algorithm) to forward data from source node to a set of destination nodes in service based routing. To maintain this multicast tree, the source node periodically has to send an update request message to destination nodes. When destination node receive this request, it will reply with a reply sender message.

**Route Request and Route Reply Message Pair.** In order to detect routes (network topology), We use a pair of messages: route request and route reply message. When We want to forward data from one source node to a set of destination nodes in case of transmitting matched content to subscribers. We have to build a multicast tree with root is current node, leaf nodes are destination nodes. We have to make update request message, broadcast this message to network. When this message reaches destination nodes or forwarding nodes that have up-to-date route information, a reply message is created to send to source node. After specified time-out the source node have received enough route information from destination nodes to source node. We use these received routes to build multiple multi-cast trees.

### 2.2 The Request/Cancel Request (subscription/unsubscription) [3, 4] Messages

Subscription (registration) / unsubscription (unregistration) message is emitted from the application service classes to subscribe/ unsubscribe content requests. The message is structured with: the address of the subscriber and binding on the list of services and content requirements (constraints). In particular, each constraint is a set of 3 components, has the form: key+operator+value. For example, the contents of the registration message: [service_class="Network monitor" alert-type ="intrusion" severity> 2] or [service_class = "Network monitor" class = "alert" device-type = "web-server"], these are 2 request messages of Network monitor service class.

**Structure of Subscription/ Unsubscription Messages.** Of which: Subscriber address is the address of required node. The service and content searching predicate: is a set of constraints. The first constraint is service binding, followed

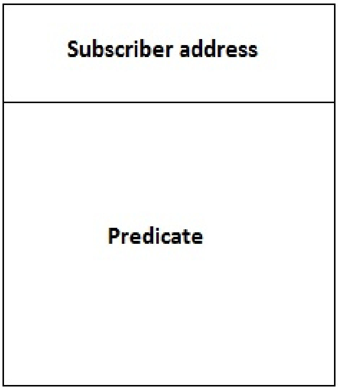


**Fig. 3.** Structure of subscription

by the content constraints. 1) Each constraint consists of 3 components: key, operator, value. 2) In which key is a string, the operator is subject to value. 3) If the value is the number then operators are: =, <, >, <=, >=, in. 4) If the value is a string then operators are : =, <, >, <=, >=, substring (sb), prefix (pf), postfix (ps). 5) If operator is sb, need to declare 2 parameters: start index v stop index specify start position and stop position for a string is extracted from value of a property to compare with value of constraint. 6) If operator is pf, need to declare number of beginning characters are extract from value of property to compare with value of constraint. 7) If operator is ps, need to declare number of ending characters are extracted from value of property to compare with value of constraint.

### 2.3 The Content [3, 4] Message

Content messages are transmitted from the host service provider. These messages will be transmitted to the network, it will be transmitted to the nodes based on the subscription request messages received from those nodes.

**Content Message Structure.** Of which: Source node address is the address of the node that generate message. The next $attribute_1$, $attribute_2$, ..., $attribute_n$ are the attributes of the message. The first attribute1 is the service information, the remaining attributes define the content of the message.

**Components of a Content Message.** Content Message includes nodes address that generated message and a set of attributes (properties), each attribute is a pair of name and value that are separated by a sign "=". The name attribute is a string. Possible type of values is string or numeric. For example, a message content: Node_a, [service_class = "Network monitor", class = "alert", severity = 6, device-type = "web-server", alert-type = "Hardware failure"].

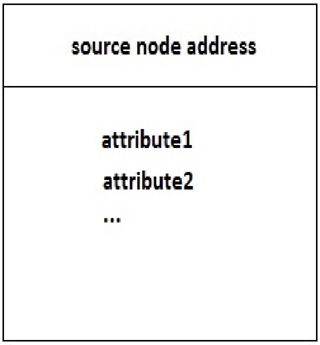


**Fig. 4.** Content message structure

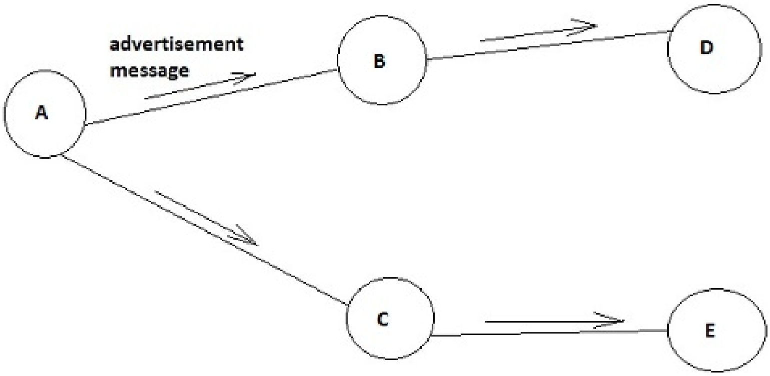


**Fig. 5.** Process of transmitting advertisement messages

### 2.4 The Advertisement Message [3, 4]

Advertisement message is the message advertises the basic content that applications for certain services provided. i) To direct the subscription requests to the right offer places. ii) Prevents spread of the subscription messages throughout the network. Naturally, subscription messages are partitioning to some smaller areas. So that We can acquire: i) decrease time to find subscription matched a content message and ii) lower cost to maintain routing table.

The advertising message is passed under the minimum spanning tree from the source node.

Advertisement message is also structured similar content message, including a set of attributes. So this kind of message is to expand the content of advertising messages. Generally use advertising message to advertise the most common content.

Advertisement message is transmitted from the service delivery system.

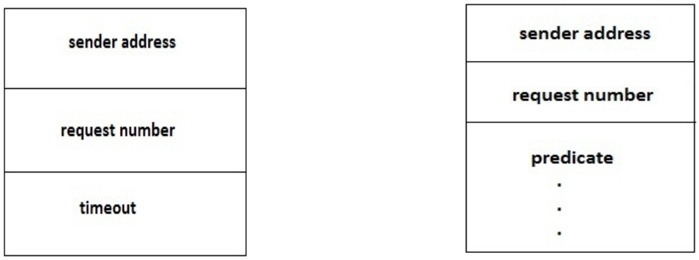


**Fig. 6.** Structures of the sender request and update reply message pair

### 2.5 Update Request and Reply Sender Message Pair [3, 4]

Sender request: request from the router, the structure including 3 fields. Two fields: sender address and request number determine the uniqueness of an sender request message. Timeout determines the longest time the sender wait for an answer. This message is transmitted by the Minimum Spanning Tree (established by PRIM algorithm) starting from the source router to the other routers in the network.

When the leaf router nodes of MST tree receive this sender request message, it will respond with a reply update (UR) message. The UR message consists of three fields, two fields from the sender request, the field no.3 contains its all content based addresses (content based routing table). The UR message spreads back the sender router.

On the way to the sender router, the intermediate routers will incorporate their content based address routing table and of the message then push it to the sender router.

When the sender router receives UR message, it updates its routing table. End of the implementation process.

### 2.6 Route Request and Route Reply Message Pair [6]

This pair of messages is used to detect routes on the network to a set of destination addresses from a source node for building multicast trees with root is source node and leaf nodes are this set of destination nodes.

Route request message: use to make a request from the source router, the message structure consists of eight fields. Two fields: 1) Source Address and 2) Request Number determine the uniqueness of the message. 3) The Type field identifies of the kind of message, is set to 1; 4) the Timeout field determines the longest time the sender node waits for a response. 5) The Time To Live (TTL) field determines the maximum number of HOPs of the route that message is passed on. 6) The Route field records addresses of the hops on the route the message passes through. 7) The Free Time Slots field records free bandwidth at the nodes of the route that message is transmitted on. 8) The Destination List field saves address list that contains addresses of the set of destination

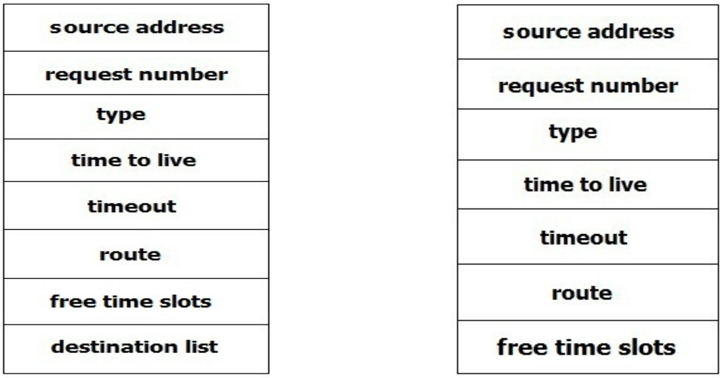


**Fig. 7.** Structures of route request and route reply message pair

nodes that are the leaf nodes of multicast trees that we need to build. The message is transmitted by broadcast protocol to other routers in the MANET. The message transmission process is indicated as following: 1) This message is transmitted from source node to any node on the network. 2) At any node (N) that message has been received: i) if Timeout is less than current time then drop this message, ii) otherwise the node will update the 3 fields of the message: Route (Route=Route U $Address_N$), Free Time Slots , Time To Live (TTL=TTL-1), assume previous node is Np, TS denote Time Slot. 3) If TTL=0: drop this message. 4) If number of free common Time Slots between current node and last hop-sender is equal to 0 then this node cannot be in route from source to any destination node: drop this message. 5) Otherwise: i) if the node firstly receives message then: a) if the node is not a destination node, node will forward this message to network; b) if node address is in destination list, create reply message to transmit to the source node. ii) If node have received this message, it will immediately make route reply message (RREP) to transmit to the source node.

The RREP message contains almost information from RREQ message, besides the type field is set to 2 and doesnt have destination list field. RREP message is sent back to the source router.

## 3 Some Channel Access Techniques

In order to build multicast tree with guaranteed bandwidth and latency. We have to use specific techniques to measure link bandwidth between any two nodes in networks.

Channel access technique is the main task of the MAC protocol. There are some channel access techniques for wireless networks: TDMA, CSMA and polling, etc.

### 3.1 FDMA (Frequency Division Multiple Access)

FDMA is primary channel access technique, in which a subscriber is regulated a frequency to be recognized by Mobile Switching Office. One inadequate problem is when two subscribers use a common frequency, tend to one subscriber can not call.

### 3.2 TDM (Time Division Multiplexing)

An subscriber is assign one specific time slot, by which subscribers data is transferred. After time slot run out, the subscriber will have to wait. For TDM, a dedicated time slot always is assigned to any subscriber, even if that subscriber does not use it. For example ISDN is ground digital telephone network that uses TDM channel access technique.

### 3.3 TDMA (Time Division Multiplex Access)

Operation Time Division Mechanism:

It is very similar to above TDM, an subscriber is assigned a specific time slot, through which subscribers data can be transmitted. After time slot run out, the subscriber have to wait. When assigned time slots run out, these time slots are released and can be assigned for another subscribers. Typically, time slots are assigned dynamically, a node can be received different time slots once accessing network.

A specific node (base station), is responsible for coordination of the network nodes. Channel time is divided into time slots, one time slot has a fixed size. Each node is granted a fixed number of time slots in which it can transmit. GSM uses TDMA in combining with FDMA technique to access network.

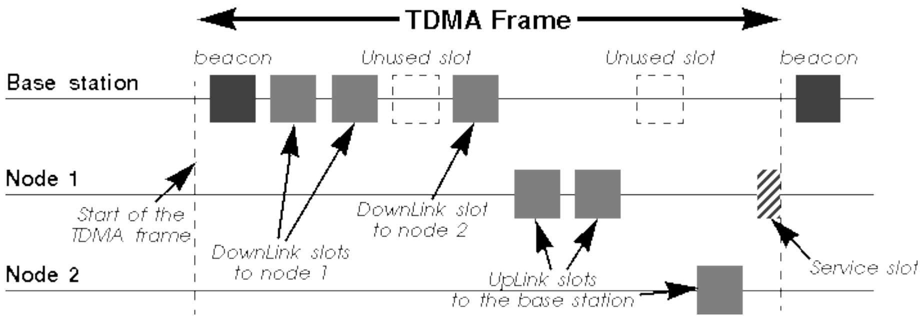


**Fig. 8.** TDMA channel access technique

Operating Principles:

All exchanges are made through this base station. TDMA is used in the mobile phone standard. TDMA allows for low latency and guaranteed bandwidth.

TDMA is not well-suited for applications that transfer data, because it's tight and inflexible. TDMA depends on the spectrum quality. TDMA can not cope with and matches the strong interference sources such as the unlicensed band.

### 3.4 CDMA (Code Division Multiplex Access)

CDMA employs a spread-spectrum technology and a special coding scheme, where each transmitter is assigned a code to allow multiple users to be multiplexed over same physical channel. TDMA divides access by time, while FDMA divides it by frequency. CDMA is a form of spread-spectrum signalling, since the modulated coded signal has a much higher data bandwidth than the data being communicated.

### 3.5 CSMA / CA (Carrier Sense Multiple Access / Collision Avoidance)

This is a channel access technique is used by most wireless LAN under ISM band. This channel access technique is a part of the protocol that shows how to use the media, when listening and communicating to avoid conflict.

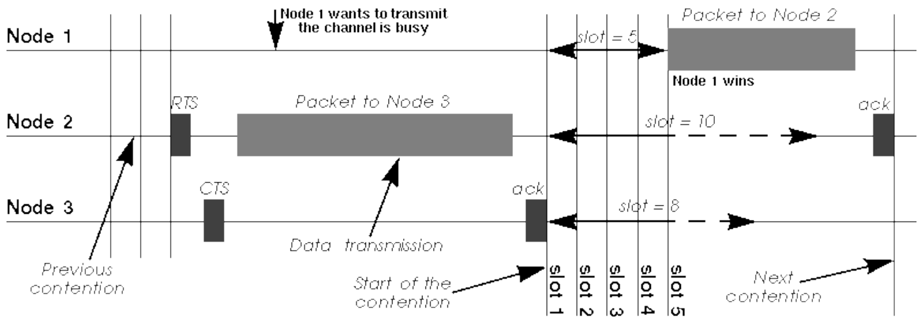


**Fig. 9.** CSMA/ CA channel access technique

After waiting for a data transfer session ends, the node waiting a period of a random integer number of time units is specified. Node has waited completely first that will have right to transfer.

### 3.6 POLLING

This is the main channel access technique, the networking standard using polling success is 100vg (IEEE 802.12), a wireless standard also uses it. For example, the 802.11 standard recommends the use of polling channel access technique with CSMA/CA.

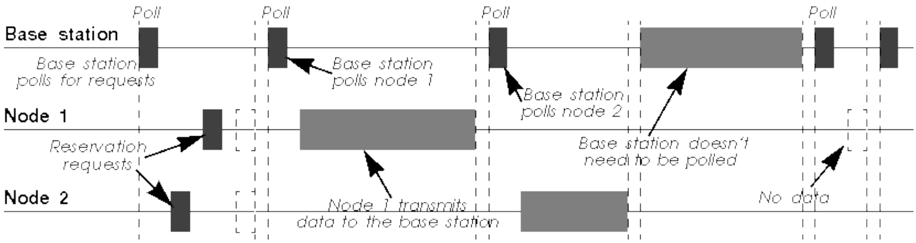


**Fig. 10.** Polling channel access technique

This channel access technique is between TDMA and CSMA/CA techniques, the base station to maintain control over the entire channel. No fixed-size packets are sent over the network. Base station sends the packet to ask (poll packet) to request node that it can send. Polling can be implemented as connection-oriented services, almost like TDMA but with more flexible packet size, or can be connectionless.

Therefore in this paper We use TDMA channel access technique to calculate link bandwidth as presented in the following section.

### 3.7 Quality of Service (QoS) Requirements

Nowaday, MANET often has been used to transmit multimedia data of online transactions in commercial applications. So We have to guarantee bandwidth and latency when transmitting data. But by mobile and loosely structure, infrustructure of MANET is often violated by many kinds of malware.

**Some Causes of Network Congestion in MANET** (a) A new route has admitted a node that is a part of other routes are overloaded with traffic at the network layer. (b) Data speed of channel or application is greater than the queue size of MAC layer (Media Access Control) (cause congestion at the MAC layer). (c) Many neighboring nodes attack network. (d) Denial of Service (DoS) attacks can occur at any layer in the network [2]. (e) The node with malicious intents can push up the network with the routing information is not correct, or delete all the packets passing through it. Node can also depend on MAC layer to make the network to be always busy or make a maximum throughput of the channel [2].

**Some Quality of Service Requirements [6]** To transmit data in Manet network effectively, to avoid congestion. We have to build a multicast tree with quality of services assurance from the source node of the message to the set of required destination nodes. The information for building tree is taken from Response Packet - Route Reply packet pair for detecting route.

These factors ensure service quality in service-oriented routing:

a) BANDWIDTH Using time slot [6] parameter to calculate bandwidth in Manet network using Time Division Multiplex Access denoted by TDMA. Divide the time interval regulated in each node as a number of equal time units,

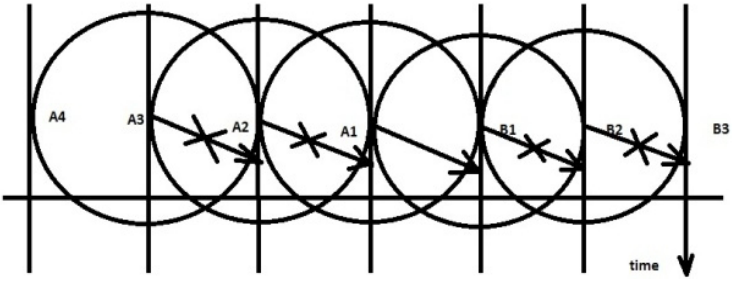


**Fig. 11.** Interference range and transmission range

each unit is called a time slot. Because the use of time slots at different nodes is very different hence to find routes that are ensured bandwidth is difficult. We have to assign time slots for all links of a route to make sure to avoid radio interference between the nodes to transmit and receive data efficiently. When time slot of one node of a link is assigned at order x (x is integer), We cant assign time slot at the same order x for 1-hop or 2-hop neighbors.

We define link bandwidth is a number of common free time slots of two nodes that form the link [6]. For example, link bandwidth between two nodes A and B [5] is as following figure:

Bandwidth of a route is defined by minimum bandwidth of all links that form the route [6].

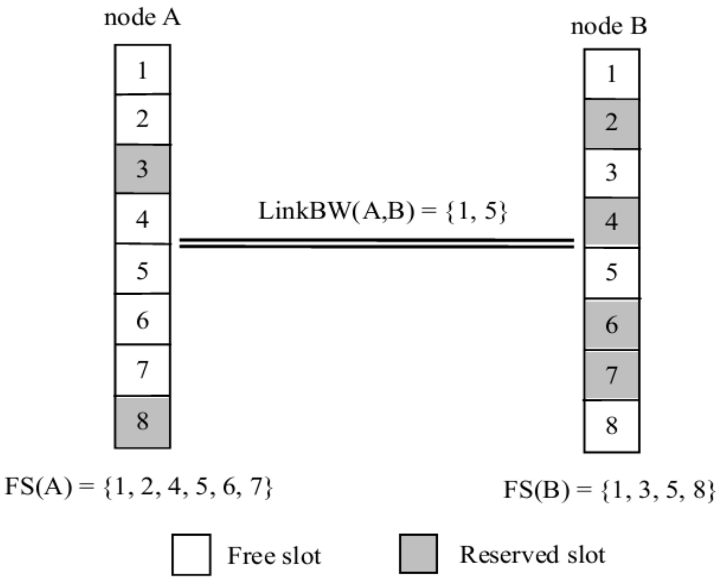


**Fig. 12.** An example of link bandwidth

Assume We have a route consists of N links, each time cycle has definite K time slots, therefore each link has maximum K free time slots. Status of each time slot at the moment of assignment is denoted by a(i,j), x(i,j) denotes time slot assignments result of time slot j of link i. a(i,j) has two values: 0 if slot is free, 1 if slot is not free. x(i,j) has two values: 1 if this time slot is assigned for the route, 0 if otherwise. Hence, in order to have route has maximum bandwidth, We have to assign maximum number of time slots for each link. We have several conditions that time slot assignment has to satisfy:

1. $\sum_{j=1}^{K} x(i,j) = \sum_{j=1}^{K} x(i+1,j)(1 \leq i \leq N-1)$ 2. $x(i,j) + x(i+1,j) + x(i+2,j) \leq 1(1 \leq j \leq K)$ 3. $a(i,j) + x(i,j) \leq 1$ (1) - Conditions for time slot assigning algorithm

Calculation of route bandwidth based on the assigned time slots for each link. The route bandwidth calculation is performed by the following principles [5]: 1. The calculation starts from the link that is in a state of worst bottle-neck, that is, have some at least time slots. If there are more than one link that have equal minimum number of time slots, We use the following formula to select link to start the algorithm:

a) Assume We have defined k constant numbers that have descending order: $W_1 > W_2 > \ > W_k$. b) We have k values $numberTS_h(1 \leq h \leq k)$, where $numberTS_h$ is the number of free time slots at time h. All these numbers are free for just k times in each of its concerned links. c) Calculate: CALCULATE_INDEPENDENCE=$\sum_{h=1}^{K}(W_h * numberTS_h)$ (2) - Formula to check link independence

for all links that have equal minimum time slots. d) We choose link that has CALCULATE_INDEPENDENCE is maximum. 2. Estimate bandwidth w of a route by formula: w=min(t/3,g), in which: t is the total of time slots, g is total of free time slots of start link. 3. We call that link is $L_min$ that connects two nodes A, B. Select w time slots from free time slots of this link which are not used by its 1-hop and 2-hop neighbors links. Then continue the bandwidth calculation (assign free timeslots) for other links in the two directions of the route. 4. Calculate bandwidth of next links for nodes from B to destination node of the route. 5. Calculate bandwidth of previous links for nodes from A to source node of the route. *The algorithm to calculate link bandwidth of two nodes A and B [5] is:* 1. Find all common free time slots between two nodes A and B, we have a set T of time slots. Select w time slots from T by the following algorithm: Suppose current link is denoted by li, it has four 1-hop, 2-hop neighbors links that are $l_{i-2}, l_{i-1}, l_{i+1}, l_{i+2}$. We choose w time slots from T according to the order of their free times in five successive links $l_{i-2}, l_{i-1}, l_i, l_{i+1}, l_{i+2}$. The time slot of fewest free times will be chosen. 2. Delete above selected w time slots from the free time slots of 1-hop and 2-hop neighbor links. 3. If We cant choose w time slots from T, the estimated routes bandwidth is decremented by Then We repeat to assign bandwidth for this link. *The algorithm to calculate bandwidth of next links for nodes from B to destination node [5] is:* 1. Assume current link between two nodes Bi and $B_{i+1}$ exists. 2. Find all common free time slots between two nodes $B_i$ and $B_{i+1}$, we have a set $T_i$ of time slots. 3. We choose w time slots from Ti according to above algorithms. If it cant be chosen then the estimated routes bandwidth is decremented by 1 and repeat bandwidth assignment from the beginning. 4. We remove above w selected time slots that are free time slots between two nodes $B_{i+1}$ and $B_{i+1}$'s 1-hop neighbor from the set $T_{i+1}$. And We update state for that free time slots for calculating bandwidth of link between $B_{i+1}$ and $B_{i+1}$'s 1-hop neighbor. 5. Remove w above selected time slots that are free time slots between two nodes $B_{i+1}$'s 1-hop neighbor and $B_{i+1}$'s 2-hop neighbor from the set $T_{i+2}$. And We update state for that free time slots for calculating bandwidth of link between $B_{i+1}$'s 1-hop neighbor and $B_{i+1}$'s 2-hop neighbor. *The algorithm to calculate bandwidth of previous links for nodes from A to the source node [5] is:* 1. Assume current link between two nodes $A_i$ and $A_{i-1}$. 2. Find all common free time slots between two nodes $A_i$ and $A_{i-1}$, we have a set $T_{i-1}$ of time slots. 3. We choose w time slots from $T_{i-1}$ according to above algorithms. If it cant be chosen then the estimated routes bandwidth is decremented by 1 and repeat bandwidth assignment from the beginning. 4. We remove time slots that are free time slots between two nodes $A_{i-1}$ and $A_{i-1}$'s one-hop neighbor from the set $T_{i-1}$. And We update state for that free time slots for calculating bandwidth of link between $A_{i-1}$ and $A_{i-1}$'s one-hop neighbor. 5. Remove time slots that are free time slots between two nodes $A_{i-1}$'s one-hop neighbor and $A_{i-1}$'s two-hop neighbor from the set $T_{i-2}$. And We update state for that free time slots for calculating bandwidth of link between $A_{i-1}$'s 1-hop neighbor and $A_{i-1}$'s 2-hop neighbor. s b) LATENCY Use hop count on a route to determine latency for that route. We define latency of the multicast tree is the length of the longest route from one of the leaves to the root of the tree. c) ERROR FAILOVER (The ability to overcome errors) This is important characteristic for the network remains stable operation in case of node errors or link errors / broken.

## 4 Algorithms for Building Minimum Spanning Tree

### 4.1 Build Shortest Path Tree Based Multiple Paths[6](SPTM)

Building Multicast-tree that has the shortest path by hop on the multi-path route from the root node to the leaf nodes. That can guarantee the bandwidth and latency. Because It is hard to find any route to be sure guaranteed bandwidth. We should include the concept of multiple-paths routing, in every part of the route We find all possible paths. So the bandwidth of the route will equal to the total bandwidth of all possible paths:$BW_{route} = \sum_{i=1}^{n} BW_{path_i}$. If there are multiple candidate paths to each path segment, they are sorted by shortest-path-first rule. So it is easy to find Multicast Tree that ensures bandwidth and latency requirements.

### 4.2 Build Least Cost Tree Based Multiple Paths (LCTM)

Building multicast tree that has the total cost of all paths is minimum which is calculated by summing the cost of the links which form quality of service

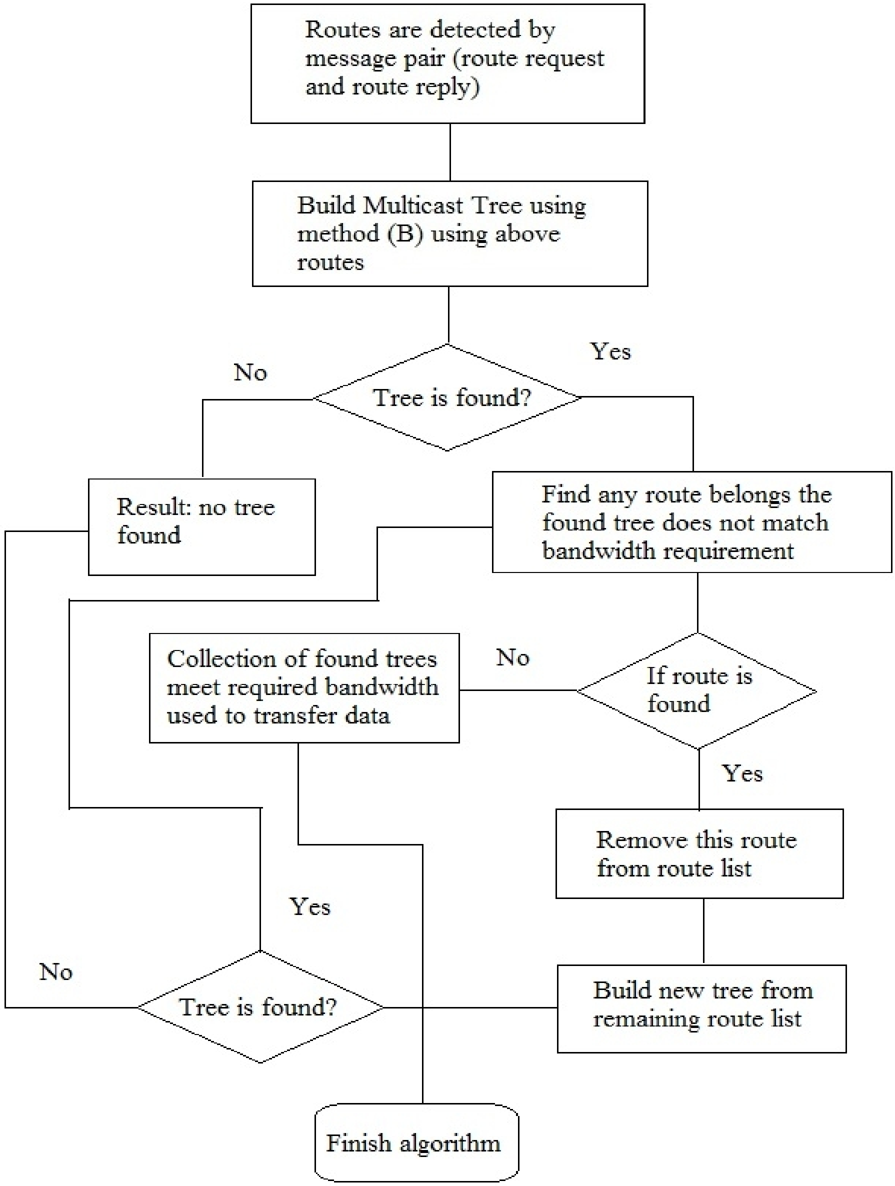


**Fig. 13.** Algorithm diagram for building Multiple Least Cost Trees

multicast tree. This kind of Multicast Tree can be built by PRIM algorithm. Hence the cost of the tree is equal to total cost of the links that have made tree: $C_tree = \sum_{i=1}^{n} C_{link_i}$. Cost of link is evaluated based on bandwidth, latency. To ensure the required bandwidth, We also introduce the concept of multi-path routing for each part of the route. On each part of route, We will find all possible paths based on the route detected messages pair as shown above. This method has the advantage of guaranteed bandwidth but greater latency at the destination node.

### 4.3 Build Multiple Least Cost Trees (MLCT)

Building many multicast trees that have the lowest cost, the cost of tree is equal to total cost of the links that have made the tree. In which cost of links is calculated by criterion of quality of service. a) The routes of tree are detected by message pair (route request and route reply). Therefore, We can use these discovered trees to transmit messages, increase the ability to overcome errors, use load balancing, utilise bandwidth available. b) Each tree is built by the algorithm LCTM, browse through the trees routes, find any route does not meet bandwidth requirement. Removing this route, and build new tree by the algorithm LCTM. c) Algorithm stops when no tree is found or the collection of trees found if they meet the bandwidth requirements on any route that will be used to transmit data, if that are not satisfy then data transmission will be stopped. d) Split large data block into several small packets of data, the packets are transmitted on different trees, small packets are eventually combined to form the original package at the destination node. This method ensures the network is able to overcome errors, load balancing and the effective use of bandwidth. Following is the algorithm diagram:

## 5 Conclusions

We can improve the routing process in content based routing by using Multicast Tree. We can build Multicast Tree by process of transmitting route requests and receiving route reply messages shown above. By using TTL (time to live) parameter so We can build trees that have bound delay by hop count. Otherwise by calculating route bandwidth, We can use one of three strategies presented above to build trees with guaranteed bandwidth. By using timeout parameter can avoid flooding data to network. Multicast Trees can reduce network load, avoid flooding data all over network, balance network load, failover, etc. The complexity of three strategies to build multicast trees depend on number of routes detected (R_SET_RESULT) received by route reply messages. Each route has maximum of TTL hops and bandwidth is more than 0. Hence complexity to find a multicast tree from source node to a set of destination nodes is O(R_SET_RESULT). If We concern only finding multicast tree is bounded by delay (hop count), complexity is O(R_SET_RESULT). After a delay bounded multicast tree is found, We can compute bandwidth of every route from source node to each destination nodes by above presented link bandwidth calculating algorithm. The complexity of this algorithm is depended on length of the route $L_R$ and estimated routes bandwidth W, that is $O(L_R * W)$. If We can find any route or any part of a route of tree that does not meet bandwidth requirement, the source will run an algorithm according to one of three multicast tree building algorithms presented above to find another route or paths of current route in addition to this route or current path of it to meet bandwidth requirement. Or We can find another least cost trees from the source node to all the destination nodes in addition to this tree. If We can find multiple multicast trees that aggregated tree satisfies bandwidth requirement, split original message into multiple small messages to transmit concurrently on these multicast trees. On destination nodes We combine separated messages into original message. Hence We can utilise better network resources, it causes data transfer rate be higher, load balancing, failover.

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## References

1. Cao, F., Singh, J.P.: Efficient Event Routing in Content-based Publish-Subscribe Service Networks. In: Proc. IEEE Infocom (2004)
2. Kalaiarasi, R., Getsy, S., Sara, S., Pari, N., Sridharan, D.: Performance Analysis of Contention Window Cheating Misbehaviors in Mobile Ad Hoc Networks. International Journal of Computer Science & Information Technology (IJCSIT) 2(5) (October 2010)
3. Carzaniga, A., Wolf, A.: Forwarding in a Content-Based Network. In: Proc. SIGCOMM (2003)
4. Carzaniga, A., Rutherford, M.J., Wolf, A.L.: A Routing Scheme for Content-Based Networking. In: Proc. IEEE Infocom (2004)
5. Li, J., Wakahara, Y.: Time Slot Assignment for Maximum Bandwidth in a Mobile Ad Hoc Network. Journal of Communications 2(6) (November 2007)
6. Wu, H., Jia, X.: QoS multicast routing by using multiple paths/trees in wireless ad hoc networks. Research supported by a grant FFCSA. Elsevier BV (2006)