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Establishing Video Multicast Over TDMA-Based Wireless Mesh Networks Using SVC

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Abstract

In video multicasting over time division multiple access, each receiver has its own quality demands. The transmission must be made possible with minimum schedule length by satisfying the receiver constraints. By utilizing scalable video coding, the proposed framework provides all together in an effective way such that routing, scheduling and rate allocation. Even if the schedule is not feasible with minimum length, the rate allocation algorithm generates feasible schedule by adjusting the transmission rates of relay nodes and the receiver utility is maximized. This framework provides splitting capabilities by considering bandwidth allocation in order to make the transmission easier. It also enhances the transmission by providing security with key generation at sender and key verification at receiver with the transmitted video packets. Finally the video is received at destination by providing the secret key and it outperforms existing schemes in terms of schedule length and security.

Keywords

SVC (Scalable Video Coding), Routing, Scheduling, Rate Allocation, Wireless Broadcast Advantage (WBA), Wireless Mesh Network.

I. Introduction

Wireless mesh network is a multihop network, where nodes are with limited mobility compared to wireless sensor networks. This network includes mesh routers and mesh clients which provides effective transmission through one or more intermediate nodes when one node can no longer operate [1]. Minimizing energy consumption is a critical issue in wireless sensor network. In contrast to that, energy consumption is not a critical issue in WMN since nodes are easily rechargeable.

In time division multiple access (TDMA) based wireless mesh network, bandwidth is divided into number of time slots. Slots are assigned to links in unicast communication and in multicast communication slots are assigned to nodes. In TDMA-based WMN the most important issue is how to find a multicast route and how to schedule the transmissions with consideration of the WBA and the spatial reuse. In multicast communication, packets transmitted from sender are received by all nodes within the transmission range; which is termed as wireless broadcast advantage (WBA). Spatial reuse is that a number of nodes can be allocated to slot until they do not conflict with each other.

It is necessary to schedule a transmission with minimum schedule length by satisfying demand rates of receiver. The required number of time slots to serve traffic demands is termed as schedule length. For efficient use the schedule length should not exceed the available number of time slots in a given schedule period.

To allocate the transmission rate of each relay node in a multicast tree Scalable Video Coding (SVC) technique is used. With SVC, a video stream is encoded at the highest resolution and divided into layers such that each receiver can decode the video stream at its preferred rate and resolution. The base layer displays the minimum quality video frames, and additional layers, namely the enhancement layers provide resolution. An effective rate allocation scheme to determine transmission rate is that, higher transmission rate should be allocated to higher level nodes of the tree than to lower level children.

The goal of the proposed framework is to effectively allocate the limited time slots such that, if the length of the resultant schedule does not exceed the available number of time slot, the schedule is accepted. Otherwise, if the schedule is not feasible due to the limited number of time slots, the rate allocation algorithm adjusts the transmission rate of each relay node to obtain a feasible schedule. A conflict-free precedence constraint graph (CFPCG) is newly defined by extending the concept of a precedence constraints graph (PCG) for scheduling and rate allocation.

II. Related Work

Wireless mesh network comprises of multiple number of nodes in which, each node not only acts as host but also as a router in order to forward packets on behalf of other nodes [1]. It is necessary to construct a minimum-energy-multicast tree (MEM) to provide effective multicast routing schemes in wireless multihop networks [2, 3]. Constructing a multicast tree by minimizing the total energy required to deliver the stream to multiple nodes is termed as MEM problem. Multicasting in multihop wireless networks focuses on finding a multicast route that minimizes energy consumption at relay nodes by maximizing the network life time [4, 5].

In multihop network, each node maintains a routing table for each known destination. The routing table lists the next node to which a packet for that destination should be sent. And the drawback behind this is that, if the routing table become inconsistent then the packets loop in the network. Also if the table contains incorrect information, then the packets can be dropped [6]. The multicast routes are discovered through packet flooding rather than taking the consideration of topology information. Ad-Hoc On-Demand Distance Vector Routing Protocol (AODV) establishes unicast route and builds multicast trees on demand to connect multicast group members. It also provides loop free routes for both unicast and multicast while repairing broken links. Lightweight Adaptive Multicast (LAM) protocol is used for finding routes and it reduces the amount of control overhead generated [7]. Drawback is that it leads to periodic beconing due to unnecessary bandwidth consumption. And the core node may sometimes lead to failure. Level Channel Assignment (LCA) algorithm and Multi Channel Multicast (MCM) algorithm are introduced to improve throughput for multichannel and multi-interface mesh networks. The algorithm minimizes the number of relay nodes and hop count distances between the source and destinations [8]. Partial overlapping channels are also considered here. Studies on broadcasting by considering the minimum latency, presented a broadcast tree and time slot scheduling. This involves with minimum broadcast latency in a single-rate wireless ad hoc network, which is a NP-hard problem and provides a polynomial-time approximation algorithm [9]. Multicast routing involves in finding a conflict-free TDMA schedules with minimum scheduling delay. TDMA scheduling algorithms find the minimum number of slots required to schedule end-to-end rates [10].

III. System Architecture

As soon as the authentication process is over the user is now ready to transmit video by uploading file from specific folder. Then it checks for the bandwidth allocation for that particular video file. The user also generates a secret key before transmitting the file to destination. This relay node makes the transmission easier without any loss in data. It transfers packet to destination and receives acknowledgement.

The sender checks for the allocated bandwidth, if it exceeds the available bandwidth then it splits the file into multiple packets for further transmission, otherwise it transmit through the single relay node without any splitting of the packets.

Multicasting of packets through multiple relay nodes, in which each relay node is provided with different transmission range. The split packets are forwarded to the destination through intermediate nodes and the acknowledgement is received. The split packets are received individually in a random manner. Before merging the packets, receiver applies the secret key and retrieves them. The complete video is obtained and the acknowledgement is sent.

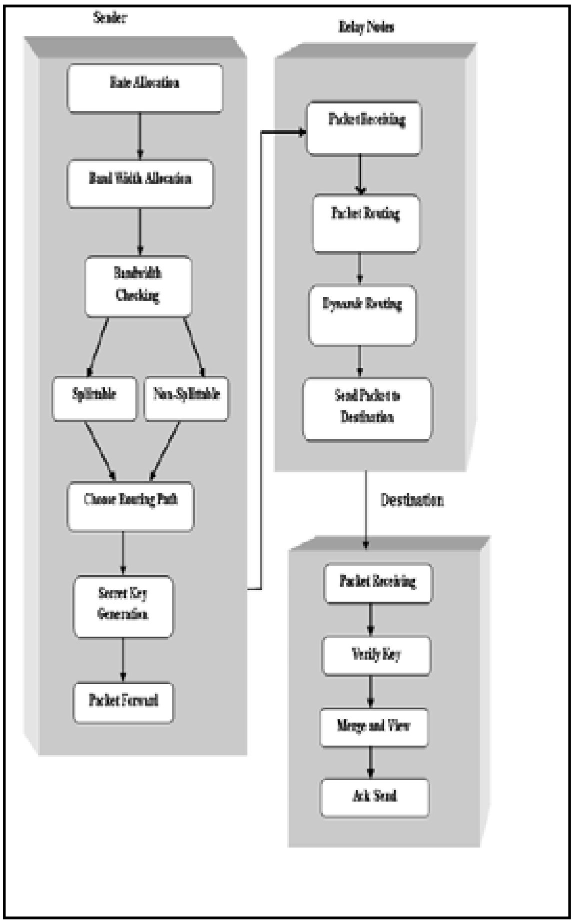

Fig. 1: Overall System Architecture

1. System Process

A. Authentication Process

User will enter the user name and password in the login form, while clicking the login button the SQL server database connection will be established and validate that particular username and password .To establish a connection with SQL server, SQL connection String is used and for query processing SQL Command text is used. Once the authentication process is over the user now can able to access the database and also can able to upload the necessary packet for receiver.

B. Routing Table and Key Generation

Routing table information is accessible only for authorized user, they can insert, update, delete and clear the table data. The table usually contains destination IP Address, Next Hop IP Address and cost information to establish a connection from source to destination. Before the sender maps the video packets with the destination IP address it generates a secret key with a key generation technique. As soon as the key is generated it checks for the bandwidth allocation for the further transmission of the process.

C. Relay Node Generation

The intermediate node between the source and the destination will act as a relay. Dynamic Hash Table is maintained in each relay node. It contains source IP, Destination IP, Next Hop IP, Packet Name, Date and Time of packet transmission. This relay node avoids the packet flooding in overall transmission of video and the number of these nodes depends upon the splitting of packets based on the allocated bandwidth.

D. Rate Allocation

More specifically, the rate allocation must satisfy the constraint that an equal or higher rate should be allocated to a higher level node of the tree than the lower level children in the same path to relay the video frames.

In other words, for a multicast receiver to receive a video stream at its demand rate, all the ancestor nodes in the path should have time slots that are at least equal to or higher than the demand rate. This rate allocation module automatically adjusts the transmission rates of relay nodes if the schedule is not feasible with minimum length and this also achieves increase in receiver utility.

E. Packet Making

Authorized user can upload file such as Text, Word and Image. And then the end user will split that file into some N number of packets Theses packets will be stored in the local system at C drive now theses packets will be send to the destination one by one manner.

While selecting the first packet one pop-up window will appear and we can select the destination IP Address, the corresponding Next Hop IP Address of the destination node. While sending the second packet, the path will be randomly chosen by using the random process. All these packets are sent through relay nodes with its own secret key.

F. Destination

All split packets are received in the destination one by one from various routing path using random process. Before the receiver merges all packets, key verification technique is applied. Receiver

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provides the secret key in order to receive all packets without any fail. Received individual packets are stored in a single location and then the packet details are viewed. Finally all these individual packets are merged into single file to get the complete video. Thus, the original file is transmitted from sender to receiver in a secure manner.

IV. Proposed Framework

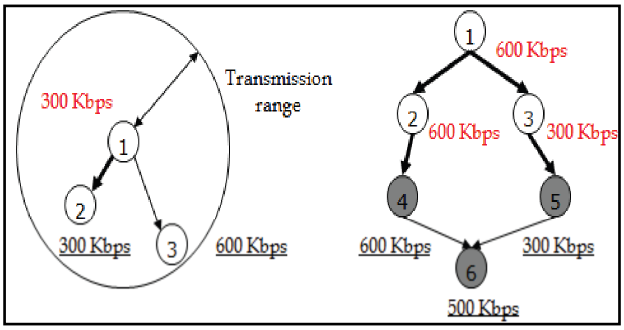
A. Multicast Tree Construction

Construction of multicast tree that satisfies the demand rate of each receiver and which also minimizes the transmission rate of all relay nodes (MTRMT). This includes a heuristic algorithm, Multicast Tree for Heterogeneous Demand (MT4HD) is shown in Algorithm 1. The main idea behind the heuristic algorithm is to find out the minimum cost path and to reduce the overall transmission rate.

```
Input: A network graph G=(V,E), source node s, and
multicast receivers sorted by the demands M⊆ V
Output: A multicast Tree T. txRate_req(i) for ∀i ∈ T
T ← ∅ ∪ {s}
txRate_req(s) ← maxDemand
Set a level to each node with BFS
for l = 1; l < maxLevel; l = l + 1 do
  S ← {node v|v belongs to level l}
  M_S ← M ∩ S
  While M_S not empty do
    m ← argmax_{i∈M_S} demand(i)
    for ∀ edge e = (i,j) ∈ E do
      if j ∈ T and i ≠ parent(j) do
        cost(e) ← infinite
      else if demand(m) − txRate_req(i) < 0 do
        cost(e) ← 0
      else do cost(e) ← demand(m) − txRate_req(i)
      end if
    end for
    path ← Dijkstra (s, m, cost)
    for ∀ node i ∈ path\m do
      if txRate_req(i) < demand(m) do
        txRate_req(i) ← demand(m)
      end if
    end for
    M_S ← M_S − {m}
  end while
end for
```

Algorithm 1: MT4HD

MT4HD exploits two properties WBA and DRAC. Figure. 2 shows the two properties. Thick lines represent edges that are already included and thin lines represent edges not yet included. Underlined numbers represent demand rate and other represent allocated transmission rate.



(a) (b)

Fig. 2: Two properties of video multicast, (a) WBA. (b) DRAC.

In the Figure. 2a, if edge (1,2) is taken as a part of multicast tree, the additional transmission rate required for edge (2,3) is not 600 Kbps but 300 Kbps. Figure. 2b shows that the transmission rate of a node should be equal to or greater than that of its descendant nodes. In the figure, if node 6 is attached to node 5, node 3 should transmit video streams at 500 Kbps to node 5. The idea of MT4HD is to find the minimum cost path from source s to receiver at each step by taking the two properties, WBA and DRAC.

B. Conflict Free Precedence Constraints Graph

A PCG is a directed graph in which the node set contains all jobs, where each job has individual processing time. Here the tail job of the edge should be completed before the head job of the edge starts processing. If a TDMA schedule to the precedence constraints of PCG is conflict-free, then the PCG is a CFPCG.

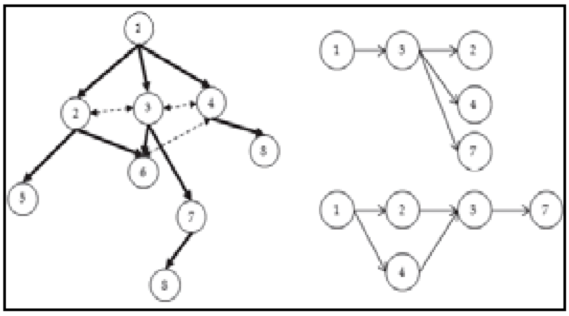

(a) (b)

Fig. 3: An example of PCG: (a) a multicast tree, (b) CFPCGs

Number of CFPCGs can be generated from multicast tree according to the precedence between two conflicting nodes as shown in Fig. 3. Here the length of CFPCG is matched directly to TDMA schedule length. It is necessary to decide the precedence to minimize the length of CFPCG.

To determine the precedence of relay nodes it includes four criteria. Algorithm 2 is constructed by using the four criteria.

```
Input: A multicast tree T, ordered relay node set V' of the tree
Output: a CFPCG of the multicast tree
r ← root(T)
CFPCG ← {r}
while V'\r ≠ ∅ do
  v ← extract the highest pritority node in V'\r
  for ∀u ∈ V(CFPCG) do
    isVisited(u) ← false
    returnValue(u) ← false
  end for
  addNodeToCFPCG (r, u, 0)
end while
bool procedure addNodeToCFPCG (node r, node v, int startLevel)
  isVistied(r) ← true
  isAttached ← false
  for ∀u ∈ child node set of r in CFPCG do
    if isVisited(u) = true do
      if returnValue(u) = true do
        isAttached ← returnValue(u)
      end if
      continue
    end if
    if addNodeToCFPCG(u, v)=true do
      isAttached ← true
      returnValue(u) = true
    end if
  end for
  if isAttached = false and CM(r, v) = true do
    CFPCG ← CFPCG ∪ {v}
    add v to r's CFPCG child node set
    set r to v's parent node
    returnValue(u) = true
    return true
  end if
  returnValue(u) = false
  return false
end procedure
```

Algorithm 2: Minimum Length CFPCG

Criterion 1 – Parent Node First

According to this, a parent node in the multicast tree has the highest precedence over its children.

Criterion 2 – Maximum Distance to Leaf Nodes First.

When two relay nodes in a multicast tree are not in the parent and children relationship, then the node that are with maximum distance to its farthest descendant leaf node have to precede the other.

Criterion 3 – Maximum Number of Descendant Relays First.

If two relay nodes satisfies the above two criterion, then the node that are with maximum number of descendant relay nodes has to precede first than the other.

Criterion 4 – Maximum Conflict Node First.

If two relay nodes satisfies all the above three criterion, then the node that are with more number of conflict nodes has to precede the other node.

Algorithm 2 usually starts with the root node to construct a Conflict Free Precedence Constraints Graph, and then it adds the remaining relay nodes based on the order of precedence. Depth first search is used here based on post order traversal. It runs depth first search as many as the number of relay nodes exists. Figure 3.a shows the multicast tree and the Figure 3.b shows two different CFPCGs that are constructed based on the above four criteria from same multicast tree.

C. Time Slot Scheduling and Rate Allocation

It is possible to schedule relay nodes optimally in O(|EPCG|) with Algorithm 3. Here the time slots are assigned to nodes based on the order of precedence.

```
Input: A CFPCG=(V,E), ordered node set V' of the CFPCG
Output: the schedule for all relay nodes (i.e. the start and end times of each relay node)
for ∀v ∈ V' do
  startSlot(v) = 1
  endSlot(v) = 1
end for
while V' ≠ ∅ do
  v← extract the highest precedence node in V'
  for ∀u ∈ v's parent node set in CFPCG do
    if endSlot(u) ≥ startSlot(v) do
      startSlot(v) ← endSlot(u) + 1
    end if
  end for
  endSlot(v) ← startSlot(v) + N_V − 1
  V' ← V' − {v}
end while
```

Algorithm 3: Optimal Time Slot Allocation with a CFPCG

At each step, this algorithm selects a node v that has the highest precedence and also selects the latest slot that is assigned to v's parents in CFPCG.

In the CFPCG, if a node conflicts with other nodes, then the node follows its conflicting nodes with higher precedence. Thus, in Algorithm 3, the start time of a node is determined by the very next time slot of its latest parent in the CFPCG. This guarantees conflict free time slot allocation between the two conflicting nodes. And finally each node in the CFPCG is assigned to its earliest possible time slot. This proves that the resultant schedule is of minimum length. It visits all nodes in the CFPCG and also checks its parent nodes. This has the complexity of this algorithm is O(|EPCG|).

Sometimes, Algorithm 3 (Optimal Time Slot Allocation with a CFPCG) does not produce a schedule length that satisfies the schedule period, if too many slots are required to support demands. In this case, time slot should be adjusted for feasible schedule length. Rate adjustment involves in maximizing the utility of multicast receivers

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```
Input: A multicast tree T, a CFPCG for the T
Output: Max-Min utility time slot allocation A (a vector
that contains the start time slot and end time slot of each
relay node's transmission)
for ∀v ∈ V(T)\leaf node do
    N_v ← 0
end for
M ← multicast receivers
while true do
    i ← find the minimum utility node in M
    if the utility of i > max utility do
        break
    end if
    v ← i's parent in T
    N_v ← N_v + 1
    for ∀u ∈ a set of v's ancestor in T do
        if N_u < N_v do
            N_u ← N_v
        end if
    end for
    A' ← slot allocation with the updates through Algo
rithm 3.
    if schedule length of A' ≤ N_D do
        A ← A'
    else do break
    end if
end while
```

Algorithm 4: Optimal Rate Allocation with a CFPCG

Algorithm 4 generates an optimal min-max utility time slot allocation. This selects receiver with minimum utility and allocate time slots to all parent node to source in order to improve the utility. This process is continuously repeated to maximize the minimum utility within limited time slots. This algorithm provides an optimal solution to max-min utility problem.

D. Enhancement

As an enhancement this system involves with checking, whether it is necessary to split the packets or not based on bandwidth allocation. Also it provides security in video transmission by a random key generation and a key verification technique for video packets.

```
Algorithm ARVTE
P(s,d) is obtained by running one of the APR algorithms.
for each call Req(s,d,r) do
    Select V from P(s,d)
    Build the auxiliary graph G(V,E) where E is the set
    of edges connecting the vertices in V that correspond
    either to existing groomable lightpaths or to poten-
    tially allocable lightpaths derived from the solution of
    RWA(s,d,r), if it exists. Set the cost of the edges to
    c(l). The edge with lowest cost shall be selected for
    tie-breaking.
    for 1 to K do
        Compute P_b(s,d) in G(V,E)
        if ∃ P_b(s,d) then
            Accept call and implement connection using the
            lightpaths corresponding to the edges in P_b(s,d).
            Break.
        else
            if N_VT(V) ≠ ∅ then
                V ⇐ V ∪ N_VT(V)
            else
                if |N_PT| ≤ p then
                    V ⇐ V ∪ N_PT(V)
                else
                    V ⇐ V ∪ {p vertices randomly selected from
                    N_PT(V)}
                end if
            end if
            Build new auxiliary graph from G(V,E) by adding
            edges for newly added vertices.
        end if
    end for
    Block call.
end for
```

Algorithm 5: ARVTE

While transmitting the video from sender to receiver, its bandwidth is checked for the allocated bandwidth. If the bandwidth does not support to allocated one, the video is then splits into multiple packets which are then merge in destination. Once the packet is ready to transmit it checks for the destination IP address and the sender generates key in order to provide security. The secret key is generated and the packets are being transmitted. The individual packets are received in destination in a random manner. All the received packets are merged by providing key verification and the complete video is obtained. Thus, the video is received by destination in a secure manner.

Algorithm 5 Alternative Routing with Virtual Topology Expansion (ARVTE) provides dynamic routing of packets from source to respected destination by establishing a virtual topology.

While transmitting a video, there is a possibility of loss of route before the packets reach the destination. In such a case it may lead to permanent packet loss. By using this algorithm, it is possible to dynamically establish a route for packets by virtual topology, in order to avoid packet loss.

V. Conclusion

Transmission of video is made possible with minimum schedule length by satisfying the different quality demands of receivers. Using scalable video coding over time division multiple access based wireless mesh network, the utility of the receiver is maximized since the rate allocation algorithm automatically adjusts the transmission rate if the schedule is not feasible with minimum length. It also provides an optimal solution for min max problem with relay node precedence. Security is also achieved in transmitting a video from sender to receiver with key generation technique. Thus the complete video transmission is achieved with effective minimum schedule length and security.

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