DSS for Video Streaming over MC MR and MH Wireless Networks

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***Abstract*— Multi-user video streaming over wireless networks is based on the utilization of available network resources effectively. In this work, this work focuses on the problem of video streaming over multi-channel multi-radio multi-hop wireless networks and to develop a fully distributed scheduling scheme with the goal of minimizing the video distortion. First a general distortion model is constructed according to the network's transmission mechanism, as well as the rate distortion characteristics of the video. Then, a distributed solution is proposed by jointly considering channel assignment, rate allocation, and routing. This paper explains the working of DSS by minimizing the video distortion and network congestion.**

***IndexTerms*— Multi channel, multi radio, multi hop, video transmission, QoS, distributed scheduling**

I. INTRODUCTION

Wireless networks are characterized by the use of multiple orthogonal channels and nodes with the ability to simultaneously communicate with many neighbors using multiple radios (interfaces). With the motivation of improving the performance of multi-hop wireless networks, it has been suggested to design the networks where each node is equipped with multiple radio interfaces and can operate on multiple different channels [1] [7].The new degree of freedom has been proven to potentially allow for increased capacity with respect to single-channel single-interface networks [3], [4].This is motivated by current WLAN standards where the entire frequency band is divided into multiple channels, and each radio can only access one channel at a time. Therefore, if each network node has multiple radio interfaces, it can then utilize a larger amount of bandwidth, and hence achieve a higher system capacity [2], [3]. Such an improved bandwidth and capacity network poses a bright application foreground for large data video communications. However, there are huge and different kinds of videos streaming from different users which may influence each other and thus, it is essential to enforce a scheduling policy designed for suitable video metrics and efficient network utilization, preferably in a distributed manner. Indeed, the problem of video scheduling over multi-channel multi-radio networks is, compared to traditional data communications in wireless multi-hop networks, further complicated by the heterogeneity in both the network conditions and application contents, including i) **channel-assignment**: how to assign the channels that each link should be operated on? ii) **rate allocation**: how to allocate the appropriate rate to the given channels and links? iii) **routing**: how to select the potential channels and links that minimize total video distortion? And iv) **scheduling:** when should each link be activated at each channel? These four problems interact with each other, and thus form a challenging cross-layer control problem across the MAC layer and the application layer.

In this work, the objective is to propose a distributed video scheduling scheme in multi-channel multi-radio networks so as to minimize the total video's distortion. First an objective function that balances the requests of the users and network operators is identified, and then we study how to construct a stable, dynamic and fair framework that optimizes for this objective. In this paper the term scheduling is used to refer to the combined operation of channel assignment, rate allocation and routing. Although some scheduling protocols can be obtained via extending the current algorithms in [1], [2], [5] that are known to achieve the maximum system capacity or throughput for multi-channel multi-radio networks. However, these works completely ignore the transmission content. In addition, these works target at elastic communications, where users do not have stringent deadline constraints. Therefore, due to the characteristics of video content and the deadline requirement of video applications, these solutions may not be optimal for delivering multiuser, delay-constrained video applications. Recently, many scheduling schemes have been proposed for video streaming over wireless multi-hop networks. The contributions and the differences between our work and previous related works are summarized in the following.

A novel distributed video scheduling scheme is provided in the context of multi-channel multi-radio multi-hop wireless networks. The support for multi-user video streams in this network requires appropriate joint channel assignment, rate control and multi-path routing measure, ascertaining the reasonable routes for transmitting each stream and the rate of the video to be delivered over the chosen routes. Different from previous works on video scheduling in single-channel multi-hop wireless networks [8], [11], [13] or multiple wireless networks [9], [11] in which channel assignment is not a concern, here the scheduling problem in the newly emerged networks is considered and an efficient assignment algorithm is proposed. Network congestion is considered in the channel assignment, rate allocation and routing metric, to meet the stringent delay requirement for video transmission. In addition, each video's rate-distortion characteristic is also taken into account in the joint routing and rate control procedure to provide multiple streams with various video contents. The distributed algorithms in [14],[15], [21], [22] may need lots of compute complexity and their performances may vary dramatically such that the video quality fluctuates and the perceptual quality may be poor. It is worth noting that our method is also different from [14], [15]. Specifically, we do not employ any explicit utility function. Furthermore, our scheme is operated over both links and sources, so our scheme belongs to per stream performance guarantee.

II. PROBLEM FORMULATION

For the distortion of wireless video transmission, we employ an additive model to capture the total video distortion as [10], [21], [22], and the overall distortion *Dall* can be obtained by:

$$D_{all} = D_{comp} + D_{loss}, \quad (1)$$

where, the distortion introduced by source compression is denoted by *Dcomp*, and the additional distortion caused by packet loss is denoted by *Dloss*. According to [21], *Dcomp* can be approximated by:

$$Dcomp = \frac{\theta}{R-R^0} + D^0 \quad (2)$$

where R is the rate of the video stream, θ, $R0$ and $D0$ are the parameters of the distortion model which depend on the encoded video sequence as well as on the encoding structure. Likewise, *Dcomp* can be modeled by a linear model related to the packet loss rate *Ploss*:

$$Dloss = \alpha Ploss, \quad (3)$$

where α depends on parameters related to the compressed video sequence [18]. In a bandwidth-limited network, this combined loss rate can be further modelled based on the M/G/1 queuing model. In this case, the delay distribution of packets over a multi-hop network is exponential [9], [22]:

$$Pr\{Delay > T\} = e^{-\lambda T} \quad (4)$$

where $Pr\{\cdot\}$ denotes probability, T reflects the delay constraint and λ is the arriving rate which is determined by the average delay:

$$\lambda = 1/E\{Delay\}. \quad (5)$$

Consider a multi-channel multi-radio wireless network with $\mathbf{N} = \{1, ...n...,N\}$ nodes, $\mathbf{L} = \{1, ...l...,L\}$ links, Nf nonoverlapping frequency channels and each node $n \in \mathbf{N}$ is equipped with Nn network interfaces. The basic network model is illustrated in Fig. 1. In order to take into account

possible channel diversity, we denote rcl as the rate at link $l \in \mathbf{L}$ can transfer data on channel c, provided that there are no interfering links transmitting on channel c at the same time. Besides, there are $\mathbf{S} = \{1, ...s..., S\}$ users in the system, and each user $s \in \mathbf{S}$ is associated with a source node and a destination node. The traffic from each user may be routed over multiple alternate paths. Let $[Ml\ sj\ ]$ denote the routing matrix, where $Ml\ sj = 1$ if path j of user s employs link l, $Ml\ sj = 0$, otherwise. Let $N(s)$ denote the number of alternate paths for user s, and Fsj the fraction of traffic from user s that is routed to path j.

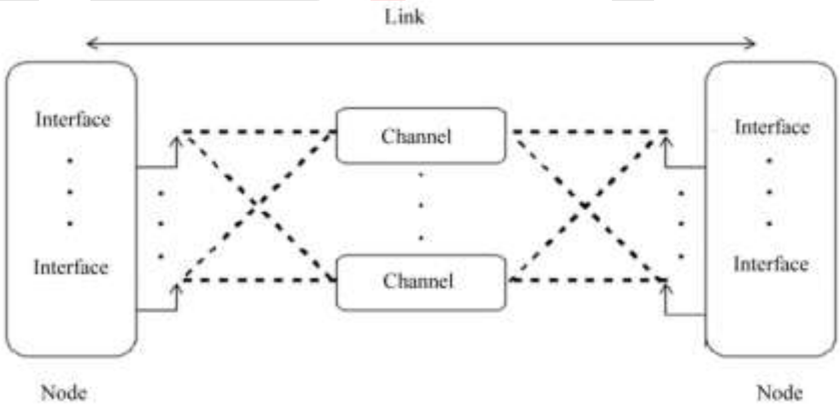

Fig. 1. Basic network model

Furthermore, let $\mathbf{Q} = [Qc]$ denote the outcome matrix of the routing scheme, where Qc is the set of non-interfering links that are chosen to transmit data in channel c. We denote *Link Balance Ratio (LBR)* [20] *ul* as the fraction of link input *rin l* and link output *rout l* for link l:

$$ul = r_l^{in}/r_l^{out}, \quad (6)$$

where

$$r_l^{in} = \sum_{s=1}^{S} \sum_{j=1}^{N(s)} M_{sj}^l \, F_{sj} \, R_s \quad (7)$$

and

$$r_l^{out} = \sum_{c.l \in Q^c} r_l^c \quad (8)$$

Rs in (7) represents the video rate of user *s*.

Considering the interference relationship, for each link *l*, it is assumed that there is a set **I***l* of links that interfere with *l*. That is, if link *l* and another link in **I***l* are transmitting on the same channel at the same time, neither of the links can transfer data, which is similar to the CSMA/CA mechanism used in 802.11 networks [20], [22]. Each radio can only tune to one channel at any given time and switch channels dynamically as in [2], [6]. Therefore, for link *l* to successfully communicate on channel *c*, both the sending and receiving nodes must tune one radio to channel *c*.

III. Distributed Scheduling Scheme

The optimization problem can be solved by a 3-step method. First, a channel assignment algorithm is proposed to simplify the goal function, and the constraints placed by nodes, links, and channels to "fix" the rate allocation and routing. The mapping relationship between the channel assignment and video distortion is constructed. Second, a joint rate allocation and multi-path routing algorithm is developed to achieve the trade-off between the coding distortion and network congestion. Third, we provide the exact operation steps for the distributed scheduling scheme based on channel assignment, rate allocation and multi-path routing. The system diagram of the distributed scheduling scheme is displayed in Fig. 2.

It can be best described in the 3- steps.

A. Channel Assignment

The proposed Channel Assignment Algorithm (CAA) is provided in Table I. During the execution of CAA, if there is a link *l* from node *n* to node *m*, then *Nc* records the number of the common channels in nodes *n* and *m*, while *Nn* and *Nm* record the number of available network interfaces of node *n* and *m*, respectively. *Nfc* represents the number of the required channels which is determined by the corresponding allocated rate in the selected link *l* and the number of available network interfaces.

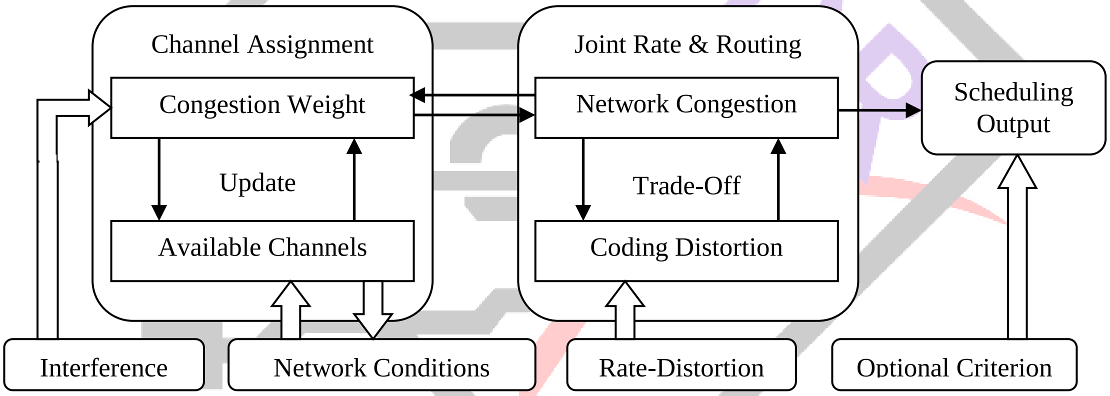

Fig. 2. Block diagram of distributed scheduling scheme.

CHANNEL ASSIGNMENT ALGORITHM (CAA)

Input:

$A(n) = \emptyset$, $\forall n \in \mathbf{N}$;

Select the links one by one in the descending order of their potential rate allocation values;

Update $A(n)$ and $A(m)$, $\forall\, n,m \in \mathbf{N}$, $l \in \mathbf{L}$;

Output:

Optimal Channel Assignment $\mathbf{A} = [A(1), \ldots A(n) \ldots, A(N)]$;

Procedure ChannelAssignment

$Nc = |A(n) \cap A(m)|$; $Nfc = Nf - Nc$;

$Nn = Nf - |A(n)|$; $Nm = Nf - |A(m)|$;

if ($Nfc > 0$ and $Nn > 0$ and $Nm > 0$)

$Nmin = min\{Nfc, Nn, Nm\}$;

Add *Nmin* channels with the smallest *congestion weight* to $A(n)$ and $A(m)$;

$Nfc = Nfc - Nmin$;

end if

if ($Nfc > 0$ and $Nn > 0$ and $Nm = 0$)

Nmin = *min{Nfc*,*Nn*, |*A*(*m*)*A*(*n*)|*}*;
Add *Nmin* channels with the smallest
congestion weight to *A*(*n*);
Nfc = *Nfc* − *Nmin*;
else if (*Nfc* > 0 and *Nn* = 0 and *Nm* > 0)
Nmin = *min{Nfc*,*Nn*, |*A*(*n*)*A*(*m*)|*}*;
Add *Nmin* channels with the smallest
congestion weight to *A*(*m*);
Nfc = *Nfc* − *Nmin*;
end if
if (*Nfc* > 0 and *Nn* = 0 and *Nm* = 0)
while(*Nfc* > 0)
for (*n* = 1, *n* ≤ *N*,*n*++)
Let *i* be the channel with the smallest
interference among channels in *A*(*n*)∪*A*(*m*);
Let *i_* be the channel with the largest
interference in *A*(*n*);
Replace *i_* by *i*;
Nfc = *Nfc* − 1;
endfor
endwhile
endif
while(*Nfc* > 0)
Assign nodes having unassigned network interface with the channels having the smallest *congestion weight* among channels assigned to their neighboring nodes;
endwhile

B. Joint Rate Allocation and Multi-Path Routing

Here a multi-path routing with the goal of finding multiple potential paths to minimize the total system congestion introduced by each user is employed. The main consideration is mainly on dividing the total rate increment of each video stream into small increments. The average delay on each link is modelled using M/G/1 queuing model.
Source s: determine the optimal path distribution for each source that includes the updating of queue length. **Link l:** determine the optimal traffic in each link that includes the rate increments updates. **Channel c:** determine the minimum congestion in each channel that includes the congestion weight updates.

Based on the given channel assignment, the joint rate allocation and routing algorithms, DSS scheme is provided to present an optimal scheduling scheme for video transmission over multi-channel multi-radio multi-hop wireless networks. The main challenges in designing DSS are how to select optimal channels, paths as well as allocated rates to ensure the performance is both stable and optimal. For DSS, each channel computes the congestion weight to make the channels assigned to spatially close nodes as different as possible, each link calculates the rates to achieve a balance between the rate increment and network congestion, and each source determines the optimal path distribution to achieve minimum video distortion. Specifically, congestion weight message is fed back from the channels to the links to avoid network congestion, queue length message is from the links to the sources to prevent the source rates from exceeding the transmission ability, and rate allocation and routing message is from the sources to the links to achieve the optimal performance.

Specifically, the sources send all of the links with path discovery messages, which are relayed by the intermediate nodes on the control channel. At each intermediate node, the path discovery messages contain the information of congestion weight and queue length related to every possible stream between the source and intermediate nodes. Then, the intermediate node extends the path as the source does. Upon reception of path discovery messages from the destinations, the sources determine the possible paths based on the feedback from the links, in form of queue length, rate increment and congestion weight. In particular, the source minimizes the total distortion while balancing the congestion of channels and links.

IV. SIMULATION OF THE DSS SCHEME

This section includes an extensive simulation to study the performance of the proposed DSS scheme in multichannel multi-radio multi-hop wireless networks. The proposed system has been implemented in NS2 simulator and analysed the performance in wireshark tool. Fig.3 shows the creation multiple paths in order to reduce the video distortion and Fig.4 shows the system performance.

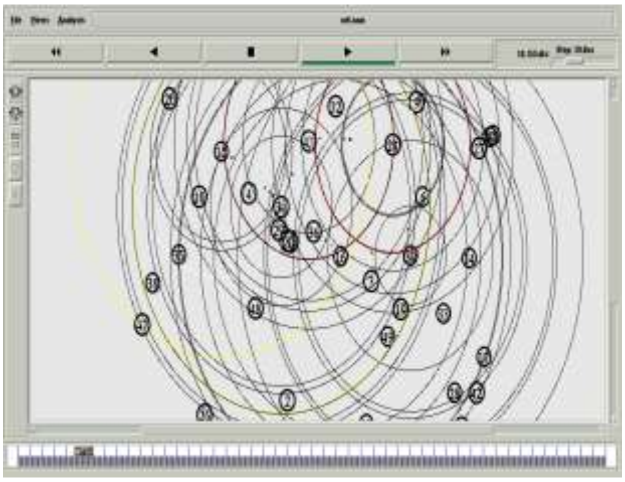

Fig.3 Multipath routing.

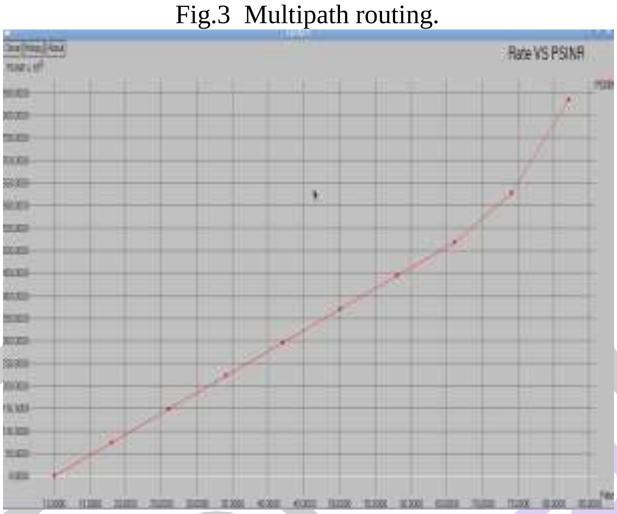

Fig.4 System performance rate versus PSNR.

V CONCLUSIONS

This paper highlights the problem of video streaming over various networks. The development of fully distributed scheduling schemes that jointly solve the channel-assignment, rate allocation, routing and fairness problems for video streaming over multi-channel multi-radio networks. Unlike conventional scheduling schemes focus on optimal system throughput or scheduling efficiency, this work aims at achieving minimal video distortion. Extensive simulation results shows the effectiveness of the proposed scheme.

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