Optimal Rate Assignment for Higher Utility WiMAX Surveillance Systems

Nedal Ababneh and Jean-Louis Rougier
TELECOM ParisTech
46 rue Barrault 75013 Paris, France
E-mail: \{ababneh,rougier\}@telecom-paristech.fr

Abstract—In this paper, we address the problem of guaranteed transmission of video flows in the context of WiMAX mesh networks for video surveillance purposes. The main design issue in such networks is to maximize the number of flows that can be accommodated in critical situations. Guaranteeing a throughput for individual flows in a multi-hop WiMAX network is a challenging task. We consider a specific dedicated architecture where communication interference can be avoided using multi-radio, multi-channel equipments where a certain latitude is offered in the configuration of video camera rates. To this end, we introduce a global utility function for the network based on the accepted video flows, their respective data rates, and the relative importance of these flows (priority). We formulate the rate assignment problem as an Integer Linear Program (ILP) that maximizes the network utility while satisfies the QoS requirements. Since the running time required to obtain the optimal solution increases exponentially with the number of nodes in the network, optimal results are only possible when the problem scale is small. Thus, the optimal solution is used for benchmarking purposes only. In this paper, we also propose new practical tree construction techniques as well as an efficient rate assignment algorithm. We compare the resulting performance of our algorithm with the optimal solution, and show that it closes a considerable portion of the gap from the theoretical optimal solution.

Index Terms—WiMAX, Wireless Mesh Network, Optimal Solution, Utility Maximization, Tree, Video Rate Assignment.

I. INTRODUCTION

IEEE 802.16 family of standards, widely known under the term WiMAX (Worldwide Interoperability for Microwave Access), was introduced in 2004 [1] as a promising wireless solution to meet the increasing demand for data bandwidth at the radio access. It is in particular interesting for guaranteed video transmission with its long range coverage, high end-to-end data throughput and efficient support for resource reservations. In this work, we consider a specific system, illustrated in Figure 1, where real-time video feeds collected at various places need to be transmitted to Collection Points (CPs), which are connected to a fixed network. CPs then forward the video data through the fixed network to a Control Center (CC). As it is may not be always possible for all cameras to directly reach a CP, multi-hop WiMAX communications are required to forward traffic to the CPs. Such an architecture can have several practical applications, in particular video surveillance in areas where fixed infrastructures (e.g. optical fibers) are not considered a practical solution (e.g., not available or for specific short term events). One of the main design issues for video surveillance application is that, the received video data rate must not fall below a certain limit as the contents must be perceivable to the security experts [2]. This implies that, the utility of a streaming video decreases dramatically if the transmission rate is not maintained above a certain limit.

Figure 1. The considered WiMAX system architecture.

To achieve efficient spectral utilization and high network throughput in WiMAX networks, the route construction within the network is a crucial task. To this end, a tree-based routing scheme easily allows traffic aggregation and ensures an optimal utilization of the limited available bandwidth. Therefore, a spanning tree(s) rooted at each CP can be used for traffic forwarding, where traffic is aggregated and forwarded by intermediate relays. Each relay is actively associated to only one tree at a given time, and can attach to one of the other trees (i.e. towards another CP) for failure recovery [3].

In this work, we consider an advanced multi-radio, multi-channel relays equipped with multiple WiMAX interfaces, some configured as Subscriber Stations (SSs) and others as Base Stations (BSs). We assume multiple frequencies are available and interfering wireless links operate on different channels, enabling multiple parallel transmissions. In order to achieve this, a specific frequency allocation scheme must be used here (Frequency allocation is beyond the scope of this paper, however, it is important to say that this subject has been extensively studied in the literature, in particular in the WIFI environment [4]). Another assumption is that each video flow can benefit from a minimum bandwidth guaranteed through resource reservation (e.g., using WiMAX service classes at layer 2 and/or DiffServ at layer 3). The problem then consists of: (1) Building efficient routing trees, and (2) Selecting the best data rate for each node (video flow) in order to maximize...
network utilization and accept as many video flows as possible without violating QoS constraints. The network and physical layers QoS constraints are translated into lower/upper bound on node data rate, an upper bound on uplink physical capacity and an upper bound on channel capacity at each relay node in the tree. In this paper, we first formulate the rate assignment problem as Integer Linear Program (ILP) that maximizes the system utility. Such an optimal solution is too complex to be used in practice for large topologies. Thus, it is merely used for comparison purposes. We discuss practical implementation for the tree construction algorithms and present a simple but, yet, efficient algorithm to compute near optimal data rate for each node (camera). We evaluate the performance of this rate assignment algorithm combined with different tree construction algorithm on random topologies. The results show that the rate assignment algorithm is very efficient and provides results close to the optimal. The algorithm helps in alleviating the performance drop due to the sub-optimality of the tree topology resulting from the use of simple distributed tree construction algorithms.

In what follows, we use the terms camera, node and relay interchangeably. The rest of the paper is organized as follows. In Section II, we provide related work, which states the difference between our work and existing solutions. In Section III, we present a formulation of the optimal solution using an ILP. Section IV presents two new routing algorithms and the proposed rate assignment scheme. The proposed algorithms are then evaluated against the optimal solution in Section V. Section VI concludes the paper and briefly introduces our future work.

II. RELATED WORK

Various related efforts have explored WiMAX in the context of video streaming applications. Geetha et al. [5] proposed a dynamic bandwidth allocation mechanism to achieve fair and efficient allocation. They presented a Generalized Stochastic Petri Net (GSPN) approach to model bandwidth allocation in Broadband Wireless Access (BWA) networks with multiple traffic classes. A dynamic weight assignment mechanism is proposed to enable fair bandwidth allocation among the competing traffic classes. Performance of the weight assignment mechanism is analytically evaluated using the GSPN model. Another research effort was conducted in [6], the authors presented WiMAX fundamentals as a broadband access solution to support IPTV services framework. The authors discussed the considerations associated with delivery video services while minimizing video and audio quality degradation. Furthermore, they presented some key transceiver design considerations at the PHY layer. There has also been effort exploring the performance of scalable video streaming over mobile WiMAX stations using feedback control. In [7], the authors evaluated MAC layer performance by scaling video content over multiple connections based on feedback of the available transmission bandwidth. The authors in [2] proposed a model to improve the utility gain of a live video streaming from cameras mounted on a public transport moving at high vehicular speeds. However, the authors did not consider the different priorities of the cameras, and all cameras are assumed to have the same level of importance. In contrast to previously proposed schemes, we offer guaranteed QoS required for video data. Although WiMAX is considered a promising technology, the offered bandwidth may be insufficient to accommodate a large number of video streams from all the cameras placed in a given area. In the above mentioned systems, when the effective throughput is scarce, data rate for all cameras drops equally and the utility of the whole video surveillance system drops significantly. In our proposed scheme, we estimate the utility for different cameras and put some low utility cameras offline and thereby maintain high utility of the video surveillance system.

III. OPTIMAL SOLUTION

In this section, we present our optimal solution for the rate assignment problem. After constructing the routing tree, as illustrated below in Section IV-A, it is up to the rate assignment phase to provide nodes with appropriate data rates. The performance of the rate assignment model benefits from well-structured routing tree. However, constructing optimal routing trees is left for our future work.

A. Notations and Definitions

The proposed WiMAX network is modeled as undirected graph \( G = (V, E) \), where \( V \) is the set of vertices representing the nodes in the network, and is composed of a group of relays, denoted as \( V_R \), and a group of collection points, denoted as \( V_B \). \( E \) denotes the set of edges that represents the potential communication network topology, i.e. edge \((v_i, v_j) \in E \) iff \( v_i, v_j \) are within each other’s communication range. Hence, the relays form a multi-hop ad-hoc network among themselves to relay traffic to the CP(s). Each edge \((v_i, v_j)\) has a physical capacity \(L_{ij}\), which represents the maximum amount of traffic that can pass through this particular link. At any given time, a node may either transmit or listen to a single wireless channel. For sake of simplicity, we assume that each relay node \( v \in V_R \) is equipped with a single camera. However, the presented model can be generalized to take into account an arbitrary number of cameras in a straightforward manner. All nodes in the network are assumed to work on the same fixed transmission power. The neighborhood of a node \( v \), denoted by \( N(v) \), is the set of nodes residing within its transmission range. Thus, a bidirectional wireless link exists between \( v \) and every node \( u \in N(v) - \{v\} \), which is represented as an edge \((u, v) \in E \). The number of neighbors of a vertex \( v \) is called the degree of \( v \), denoted by \( \delta(v) \). The average node degree in a graph \( G \) is called the graph degree \( \Delta(G) \). Once the routing algorithm has been applied, the resulting tree(s) \( T = (V', E') \) is a subgraph of \( G \), where \( E' \) represents the communication links in the final tree(s), and \( V' \) is the set of relays and CPs included in the resulting routing tree.

In order to assess the relative importance of cameras and the benefits gained when accepted in the network, we propose a utility function. The utility of a streaming video coming from camera \( v_i \) is denoted by \( U_i \). This utility depends on the minimum acceptable video rate \( W_{min} \) and the maximal
desired data rate $W_{\text{max}}$. It also depends on $P_i$, which identify the priority associated with each camera (e.g., either high or low). This value can be pre-assigned based on the geographic location of the cameras and the captured data and can be dynamically changed by an operator (e.g., via SNMP in case of specific events). We use a simple step-wise linear function for this utility function. Let $r_i$ be the current data rate allocated to camera $v_i$, then $U_i = 0$ whenever $r_i < W_{\min}$ as the flow cannot be properly interpreted at the control center (in other words, the video streaming is useless and should stop). Note that, video data can be stored locally, if possible, and will be retrieved later when the bandwidth permit. When $r_i = W_{\min}$, the utility reaches a value $P_iU_{\min}$ and then smoothly increases with $r_i$ towards $P_iU_{\max}$ for $r_i = W_{\max}$. Note that, by construction, we must have $r_i \leq W_{\max}$.

B. Integer Linear Program Formulation

Let $z_i$ be a 0-1 integer variable for each camera $v_i \in V$, such that $z_i = 1$ if the camera $v_i$ is accepted as a traffic source in the resulting tree (i.e., $v_i \in V_S$). Let $r_i$ be a positive real variable for each $v_i \in V_S$, representing the effective data rate of $v_i$, such that $r_i = 0$ if $v_i$ is not included in the resulting routing tree (i.e., $z_i = 0$). Furthermore, let $y_{ij}$ be a positive integer variable for each edge $(v_i, v_j) \in E'$, showing the amount of data transmitted from node $v_i$ to node $v_j$ (i.e., uplink effective data rate), where the receiver could be a CP node. The ILP for the routing tree construction and rate assignment problem can thus be stated as follows:

**Objective function:**

$$\max \sum_{i \in V_S} z_i \cdot P_i \cdot U_{\min} + z_i \cdot P_i \cdot (r_i - R_{\min}) \cdot U_{\text{step}}$$

The first term of the utility function is the minimum utility for each camera in the network, and the second term denotes the utility evolution with rate. Multiplying the second term by $U_{\text{step}}$ (which is equal to $(U_{\max} - U_{\min})/(W_{\max} - W_{\min})$ in this scenario) ensures utility evolution with rate. Also, multiplying the first and second terms by $z_i$ guarantees the consideration of the included vertices cameras in the resulting tree(s) only. Note that, each accepted camera $v_i \in V_S$ is assigned rate $r_i \geq R_{\min}$ from constraint 5 below. The coefficient $U_{\min}$ is the minimum utility of each accepted camera $v_i$, and must be set to any positive value greater than zero (i.e., 1 in this case).

**Constraints:**

$$y_{ij} \leq L_{ij}, \forall i \in V_S, \forall j \in V : (i, j) \in E \quad (1)$$

$$\sum_{j \in V_S \setminus \{i\}} y_{ij} \leq C_i, \forall i \in V \quad (2)$$

$$\sum_{j \in V : (i, j) \in E} y_{ij} - \sum_{j \in V : (j, i) \in E} y_{ji} = r_i \cdot W_{\max}, \forall i \in V_S \quad (3)$$

$$z_i \geq r_i, \forall i \in V_S \quad (4)$$

$$r_i \geq R_{\min} \cdot z_i, \forall i \in V_S \quad (5)$$

Constraint (1) ensures that the uplink effective rate of each included edge in the resulting tree is bounded by the maximum physical link capacity. Constraint (2) provides an upper bound (i.e., the cell capacity) on the relay load constraint, it ensures that the incoming flow is always less than cell capacity $C_i$. Constraint (3) is for flow conservation. It implies that the difference between the outgoing traffic and the incoming traffic at camera $v_i$ is the volume of traffic generated by camera $v_i$ itself. Since all data flows are originated from cameras and do not return to the cameras (i.e., nodes), it will not lead to cycles in our solution. All data flows will eventually reach the CPs. Constraint (4) ensures that camera data rate is assigned to accepted cameras in the resulting tree only, i.e., not accepted camera in the resulting tree has rate equal to zero. Finally, constraint (5) ensures that each accepted camera $v_i$ in the resulting tree has to be assigned rate $r_i \geq R_{\min}$, this is to satisfy the minimum acceptable data rate (QoS) requirements.

IV. ALGORITHMIC SOLUTION

The optimal solution of joint tree construction and rate assignment is too complex for a practical implementation in large topologies. Therefore, we chose to present a light-weight algorithmic solution for the problem. Our solution consists of two steps described in the following.

A. Tree Construction

In this section, we introduce two new cost metrics. It is important to note that the proposed metrics are computed in a distributed manner (for system robustness reasons) by the individual nodes along a given route, distributed tree construction techniques have been widely discussed in the literature such as in [8]. The cost metrics have a big impact on network performance as they actually determine the final tree structure. The adopted metrics are described as follows:

**Minimum Neighbor Path Tree (MNPT):** We define for each node $a$, a degree function denoted by $\delta(a)$, which represents the number of neighboring nodes. The sum of the degree functions of all nodes that reside in the path of a node, say node $a$, is termed the path-degree, $\delta_P(a)$. Each node in the network to choose its parent, it chooses the neighbor which renders the smallest path-degree value among all other neighbor nodes (i.e., potential parents). In fact, the path-degree metric is the sum of the node degree metric of the node’s predecessors. For example, assume CP-e-b-a is a path in the routing tree, and $\delta_P(a)$ is the sum of node number of neighbors through the path from node a whose parent node is b to the sink. Thus, this value can be calculated as $\delta_P(a) = \delta(a) + \delta(b) + \delta(c) + \delta(CP)$. When a node, say node a, is entering the network, all its neighbors are eligible to be a’s parent. In order to improve the network performance, node a selects a parent node, say node b, with smallest value of $\delta_P(b)$. The parent node is then selected such that $Prtnt(a) = \min_{i \in \text{neighbor}(a)} \delta_P(i)$.

**Minimum Children Path Tree (MCPT):** In this algorithm, the tree is constructed as in the MNPT algorithm described above while replacing node degree by the number of children of each node.
B. Rate Assignment Algorithm

The idea of the algorithm is fairly simple. To better understand the notion of the proposed algorithm, we first present it for a single level of hierarchy as illustrated in Figure 2. The algorithm consists of computing the number of flows that pass through each branch of the tree and then to assign a capacity to each branch that is proportional to this quantity.

In this particular scenario, there are a total of 6 flows in the tree with a total uplink capacity of $C$. The left branch that deliver 3 flows is assigned a capacity of $\frac{C}{2}$, while the middle branch with 2 flows gets $\frac{C}{3}$. We then check whether this amount of bandwidth is large enough to accommodate the video flows (i.e., $> W_{\min}$). If this is not the case, the number of flows that passes through the branch is reset to zero and the capacity assigned to this branch is released. It means that the cameras (flows) that pass through this branch will have to be put offline in this critical situation where there is not enough available bandwidth. The capacity of this branch is redistributed to the neighboring branches. For instance, in Figure 2, imagine that $\frac{C}{6} < W_{\min}$ so that the video flow of the right branch has to be turned off. The flow counts are modified accordingly and the neighboring branches are now assigned $\frac{C}{3}$ and $\frac{C}{4}$ respectively. Similarly, these capacity pre-assignment must also be compared to the physical capacity of each branches (i.e., $L_{ij}$). When the assigned amount of capacity is too large to be accommodated by the branch, it is then adjusted and the remaining capacity is assigned to the neighboring branches. This procedure is repeated iteratively from the tree roots (CPs) towards its leaves. When several priorities are available (we consider two priority levels in this work i.e., high and low), the algorithm starts with the highest level of priority. The remaining bandwidth is then shared by the lower level of priority by a new instance of the algorithm and so on.

The proposed algorithm runs independently at each CP (routing tree root) in a centralized manner. The three steps of the algorithm are then described as follows:

1) Initialization Step: The algorithm starts with initialization of the variables. More precisely, the number of flows with priority $p$ ($p$ is either high or low in this paper) passing through node $i$ is denoted by $F_{i}^{p}$. These values (i.e., $F_{i}^{p}$) can be calculated by browsing the tree in opposite direction, starting from the leaves and going up to the root (CP) (i.e., leaf-to-root manner), $F_{i}^{p} = \sum_{j \in \text{Child}(i)} F_{j}^{p}$. The parent node of a node $i$ is denoted by $\text{prnt}(i)$. Consequently, the set $\text{Child}(i)$ represents the set of nodes which are directly connected to node $i$. $H(i)$ denotes the hierarchical level of node $i$ in the tree. (e.g., $H(CP) = 0$, $H(i) = 1$ for a node $i$ that is directly connected to a CP, etc.). The capacity allocated to node $i$ is denoted by $UplinkCap(i)$. It corresponds to the bit rate available for this node at the uplink (how much traffic it can relay including its own generated data). This value is bounded by the cell capacity $C$ at each node (and the CPs) as well as to the physical link capacity $L_{i,prnt(i)}$. The $UplinkCap(i)$ is dynamically updated to ensure the accuracy of the algorithm based on the available capacity upstream and the number of high priority video flows. Once initialized, these $UplinkCap$ values should be coherent. In fact, the available $UplinkCap$ of a node can be greater than or equal to the nodes in the path to the CP. Figure 3 demonstrates the procedure used to ensure a node is assigned $UplinkCap$ not greater than the $UplinkCap$ of the nodes in its path towards the CP.

2) Assign Uplink Capacity Step: Next, the main capacity allocation procedure, illustrated in Figure 4, is executed (once for each priority level (high or low), starting with nodes with high priority value of $p$). Once this procedure is completed, the data rate of the nodes of priority $p$ can be then determined. Starting from leaf nodes, a leaf node $i$ will be assigned rate $r_{i} = UplinkCap(i)$, such that the QoS requirements are satisfied. The node will update its incoming and outgoing traffic ($inTraffic$ and $outTraffic$, respectively) variables to allow accurate rate allocation for upstream nodes. For leaf node $i$, $inTraffic = 0$ and $outTraffic = r_{i}$. Nodes in the upper level will then compute their $inTraffic$, and their rates will be calculated as follows: $r_{j} = UplinkCap(j) - inTraffic(j)$. The rate assignment process will recursively continue level by level until the CP is reached.

3) Final Rate Assignment Improvement Step: After the nodes’ data rates are assigned according to the previous steps,
we check for any extra available bandwidth at each node. For instance, a leaf node might be allocated an $U_{\text{linkCap}} > W_{\text{max}}$, in this case $U_{\text{linkCap}} - W_{\text{max}}$ extra bandwidth is available. In our algorithm, such extra bandwidth will be allocated to nodes without violating QoS constraints. Checking for extra bandwidth process commence in leaf-to-root manner, where unallocated bandwidth at node $i$ is computed as $U_{\text{linkCap}}(i) - (r_i + \text{inTraffic}(i))$ and will be moved to the CP to be allocated to other nodes where possible. This procedure will be repeated recursively until there is no extra bandwidth available in the network or the given constraints (QoS) are not permitting any further bandwidth allocation.

V. PERFORMANCE EVALUATION

To validate the performance of the proposed scheme, we have conducted an extensive set of experiments using a C++ coded simulator. We compare the performance of our proposal to the optimal solution, obtained by solving the ILP presented in Section III-B using a commercial version of AMPL and CPLEX. The performance is studied based on the routing trees generated according to the routing algorithms proposed in Section IV-A as well as the Shortest Path routing Tree (SPT).

In the simulations, we generate uniformly distributed random topologies with 40 nodes deployed in a 1000 x 1000 m$^2$ terrain. We randomly placed 3 CPs in the simulated region. The cell capacity is fixed at $C = 20$ Mbps. The transmission range $R_T$ is 200 m. The minimum acceptable video data rate generated by each camera $W_{\text{min}}$ is 768 Kbps (i.e., $R_{\text{min}}$) and $W_{\text{max}}$ is fixed at 4608 Kbps. We partitioned the links in decreasing order in terms of their physical length into three sets and assign the links in these three sets with capacity of 2, 5 and 8 Mbps, respectively. Priority $P$ is set to 1 for low priority cameras and 100 for high priority ones. We monitored the average utility per camera of the video surveillance system. The minimum utility of each accepted camera $U_{\text{min}} = 1$ and $U_{\text{step}} = 1/5$. Also, the utility for video transmission rate below $R_{\text{min}}$ (i.e., 768 Kbps) is considered to be insignificant, hence, we decided to put the camera offline. Utility for each offline camera is assumed to be zero, and the fraction of high priority cameras to the total number of cameras is set as $\alpha = 30\%$. In this experiment, we control average node degree by adjusting node’s transmission range, we vary the average node degree from 3 to 7. In the plots, we compare the performance of the rate assignment algorithm (termed as Hu-) to the optimal rate assignment solution (termed as Opt-), both combined with the three routing tree construction algorithms (SPT, MNPT and MCPT). Unless otherwise stated, all the following investigations adopt these values. For all simulation results in this paper, each experiment is an average of 5 different random topologies, and we are interested in evaluating (1) utility, (2) throughput, (3) quality of received video data, and (4) number of accepted traffic sources (i.e., cameras) in the network.

A. Utility and Throughput

Figures 5 and 6 plot the utility and throughput, respectively, as a function of average node degree. It is apparent that all schemes experience performance increase with the increase in node degree. This is because more routing choices are available for nodes when the number of nodes increases. The proposed schemes are good at choosing advantageous route when the node degree increases. We also observe that with the increased node degree, the proposed rate assignment algorithm is still able to achieve near optimal results, indicating that the proposed algorithm is scalable to high node density. This is because the proposed algorithm assists to make a decision whether to put camera(s) offline based on the estimated video transmission rate and calculated utility from various camera sources. The three schemes (joint routing and rate assignment) achieve a more or less equal utility. However, among all route construction algorithms, MNPT works the best which leads to the highest network throughput, followed by the performance of MCPT and SPT, respectively. This is because it selects route with minimal possible relay load at each hop, thus the packets are dispersed widely and concurrent transmission can be fully utilized. In addition, we can see that although sometimes the SPT does not necessarily indicate the higher network throughput, which is true in most cases, it performs similar to MCPT in terms of network utility in this experiment.

B. Accepted Traffic Sources

Figure 7 shows how well the proposed rate assignment algorithm performs compared to the optimal solution in terms
of number of accepted cameras (i.e., flows) in the resulting routing trees. We note that, all curves depict a higher value of accepted number of cameras for larger node degree, which suggests that increasing number of nodes in the network helps to obtain a better solution as more routes would be available, and thus more cameras could be accepted in the network. It is clear that, for node degree greater than 3, the three schemes are able to attain, almost, the ideal optimum results by accepting as many cameras in the network as the optimal degree at the highest possible data rate as illustrated further in Figure 8.

C. Quality of Received Video

The impact of average node degree on the data quality received from the accepted high priority cameras is also evaluated, due to space limitations we present here results for MNPT solution only. Figures 8 (a) and (b) show the effect of different average node degree values on the streaming data quality coming from the accepted high priority cameras, while the video data is the actual information transferred across the wireless links. We classified the video quality based on the allocated data rate (i.e., utility) into three levels: poor (768 - 2048 Kbps), good (2049 - 3328 Kbps) and excellent (3329 - 4608 Kbps). From the figures, we can see that the percentage of high priority nodes accepted at better quality (higher rates), and thus higher utility, increases with the node degree in both solutions. However, the optimal solution slightly outperforms our proposal. This is because more routes are available in the network with possibly better capacity, and the optimal solution provided by the ILP is able to select the best capacity path. As a result, the best camera rates are allocated to high priority cameras. However, it is apparent that the rate assignment algorithm is able to achieve near optimal results with fair distribution of the available bandwidth across the accepted cameras.

VI. CONCLUSION AND FUTURE WORK

In video surveillance systems, a key design requirement is that video quality must not fall below a certain limit as the contents must be capable of being perceived. In the standard system, when the effective throughput drops, data rate for all the cameras, regardless their importance, drops equally and the utility of the whole video surveillance system drops significantly. In critical situations where the available throughput in the system may not be sufficient to accommodate the streaming video data from all the cameras, we proposed a solution that decides which camera(s) to put offline so that overall utility of, especially the high priority cameras, whole video surveillance system improves. We have presented an optimal rate assignment solution to maximize the utility of WiMAX surveillance system with QoS guarantee. We formulated the problem as Integer Linear Program (ILP) and gave solution to it. We further proposed a near optimal rate assignment algorithm that does the same functions as the ILP. Simulation results have been presented to illustrate the performance of the proposed approach. It shows that the proposed rate assignment algorithm can achieve utility and throughput close to optimal solution. It also allows to use simple and robust tree construction algorithms, alleviating the impact of different tree structures. For further studies, we will focus on the optimal tree construction problem. Our aim is to find heuristics that can further improve performance while still remaining distributed and simple.

ACKNOWLEDGMENT

The work described in this paper is conducted by TELECOM ParisTech in the framework of NimbleNet project, funded by the DGCIS and labeled by the French government SYSTEM@TIC initiative. The partners of the NimbleNet consortium are Thales Communications & Security, Eolane les Ulis and TELECOM ParisTech.

REFERENCES