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QoS Management in WIDENS Terminodes

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Abstract— **The paper has two parts: First, we present an overview of the IST WIreless DEployable Network System (WIDENS) Project. This project aims to define an easily deployable communication system to be used by emergency services and public safety in general. In this context, users require a communication system that should not depend on pre-existent infrastructure, and could support real time applications, so that firefighters, policemen, doctors (and others) can collaborate efficiently. In order to meet these requirements, WIDENS implements a wireless ad-hoc network with Quality of Service (QoS) support.**

Second, the paper focuses on the QoS approach used in WIDENS. This approach is based on a bandwidth reservation scheme. Additionally, we give some simulation results showing the advantages of the reservation scheme.

I. INTRODUCTION

WIDENS (WIreless DEployable Network System) [1] is a cooperative project involving European industries and universities. The project is supported by the European Commission under the IST Framework Programme 6. The overall objective of the WIDENS project is to design, prototype and validate a high data-rate, rapidly deployable and scalable wireless ad-hoc communication system with QoS support for future public safety, emergency and disaster applications.

To make possible to attend all these requisites, the project proposes a system for an easily deployable IP wireless ad hoc network in the absence of infrastructure, that uses some of the well known wireless networks standards and proposes adaptations and changes to: (i) Adequate them better to the typical scenarios of this kind of networks, and (ii) introduce QoS support. The project pretends also to disseminate to the Mobility for Emergency and Safety Applications (MESA) standardization project [2].

On this kind of scenarios there is a great necessity in supporting many different types of applications: from file transfers and database queries where there are not QoS requirements, to videoconferences, audioconferences and video surveillance, that are very sensible to delays and jitters, and that normally need a guaranteed minimum bandwidth to work properly.

To attend all these requirements of QoS, the WIDENS ad-hoc network is composed of nodes that implement the following elements:

- A DLC/MAC/PHY based on 802.11 that provides mechanisms for reliable communication and QoS.
- A modified version of the OLSR (Optimized Link State Routing) [3] routing protocol that supports route selection based on network state and routing based on data flows, which allows to guarantee the needed QoS to applications.
- Network management components, that allows to optimize the configuration adapting it to each kind of operation.
- Security components, that guarantee the confidentiality, authenticity and reliability of the information and robustness of the system.
- Applications and group services that will be used by Public Safety units during operations.

The MAC layer developed for the project is inspired in 802.11e, 3GPP and HiperLAN/2 standards, to provide QoS. The network is organized in *clusters*, coordinated by a special node called *clusterhead*. This node has the responsibility of managing the cluster resources, assigning transmission opportunities to all nodes under its control, that is, nodes that form the cluster. On this way, it is possible to guarantee a deterministic QoS in the transmission system.

Over the MAC layer, it has been developed a network resource reservation mechanism inspired on the Resource ReSerVation Protocol (RSVP [4]) but adapted to the reality in a wireless network. The developed mechanism has been integrated with the OLSR routing protocol, so when an application needs to communicate with other node, under some minimum QoS conditions (requirements such as bandwidth and delay), a mechanism of Call Admission Control (CAC) verifies the availability of a route to the intended destination that can satisfy them. Once there is a route that can satisfy the requirements, the protocol to make the resource reservation in all nodes along the path to the destination is launched.

The paper is organized in two parts: First, sections II and III presents an overview of main components of the WIDENS

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nodes. Second, the paper explains the QoS scheme used in WIDENS: Section IV describes the QoS principles, Section V explains implementation details, and Section VI show some simulation results. Finally, section VII gives some concluding remarks.

II. The PHY and MAC Layers

One of the objectives of the project is development of physical (PHY) and medium access control (MAC) layer of WIDENS prototype system, in relation with the research activities carried out in it [5].

The WIDENS MAC looks like an enhanced 802.11e [6]. The MAC is time-slotted and synchronized by special nodes, called *ClusterHeads* (CH), which play the role of the *hybrid coordinator* in 802.11e networks. Nodes associate themselves with the clusterhead after synchronization, and can be associated with more than one, which allows for interconnection of clusters via these so-called *relay nodes*.

The role of the clusterhead is to regulate traffic within the cluster by scheduling transmission opportunities based on traffic volume measurements signaled by terminals and network layer QoS reservations. When a WIDENS terminode wants a reservation with another node, issues a layer 3 request to its MAC protocol. The layer 2 then requests the clusterhead for that resources in the cluster. The clusterhead answers with a layer 2 reservation reply. From then, the clusterhead issues transmission opportunities to the WIDENS terminode to accomplish the aforementioned QoS reservation. During transmission opportunities, terminodes can schedule their traffic queues over physical layer resources using reconfigurable scheduling policies satisfying different QoS scenarios and based on wideband channel measurements with respect to their destinations.

The software/hardware architecture for the WIDENS prototype is based on the proven PC-based real-time EURECOM software radio architecture, used e.g. by the FP5 IST Mobydick [7] platform. In this implementation the nodes consist of:

- 5MHz channels, TDD RF front-Real-time data acquisition system.
- Real-time software (RTLinux) development environment for fully-reconfigurable PHY/MAC.
- Dual-antenna (TX-RX) capability.
- IPv4/IPv6 interconnect.
- WLAN interoperability (using commercial WiFi hardware).

III. The Network Layer

With the objective of using the QoS facilities provided by the MAC layer, it has been planed the use of routing based on per flow bandwidth reservation. For this reason, it has been developed a network resource reservation mechanism, inspired on the RSVP but adapted to the reality of a wireless network. Each application that needs to send traffic with QoS requirements can request the desired bandwidth to the network, which in turn will respond with the availability (or not) of the resources needed to make the reservation.

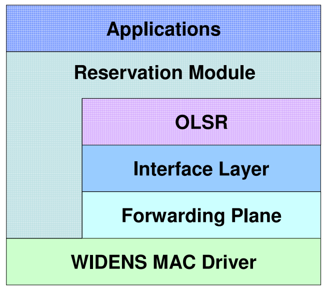


Fig. 1. Main components of the network layer of a WIDENS node

To make this possible, some modules with quite specifics functionalities have been developed, which work in cooperation to each other (Fig. 1). The Reservation Module, for example, is in charge of managing all reservation requests and of the resources liberation whenever they are not needed anymore. This module communicates directly with the routing protocol (a modified version of OLSR), which, in turn, with the aid of a Call Admission Control (CAC) mechanism, verifies the availability of a route towards the destination able to satisfy the QoS requirements (Fig. 2). Once there is a route able to satisfy the QoS requirements, a flow identifier is assigned to the reservation and the protocol to actually make the reservation in all the nodes in the path towards the destination is activated. From then all the forwarding is based on the pair source IP address and flow identifier (combination that is unique in all the network). Then, OLSR installs a new entry in the forwarding table and all packets generated by the application to the desired destination are marked with this flow identifier.

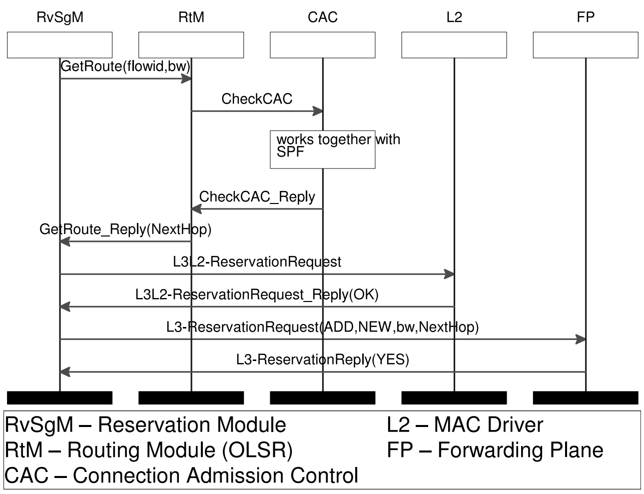


Fig. 2. Message Sequence Chart for a reservation requirement (in this case there are enough available resources)

In the following we give some implementation guidelines of these modules.

A. Forwarding Plane

One of the basis of the WIDENS project is to provide services that have strong QoS requirements (like bandwidth and/or delay). With this objective in mind, the developed MAC layer offers to upper layers the possibility of making local reservation of the resources needed for the different data flows.

Thus, with the objective of taking advantage of these features offered by the MAC layer, the forwarding plane of a WIDENS node replaces the traditional packet forwarding based on destination IP address by one based on a flow identifier (that is generated by the reservation module, described later). This way, it is possible to make reservations for a given data flow and forward it based on its identifier, using to do that the resources asigned to it on each one of the nodes along the path towards destination.

A unique identifier in the origin node is added to all packets for which a resource reservation has been done (Fig. 3). Thus, it is possible to identify a flow in all the network in a uniquely form through the pair (source IP address, flow identifier).

Using this new forwarding mechanism, the implemented upper layer modules deliver to the forwarding plane flows already classified, which are forwarded according to their identifiers and transmitted in their time slots, previously guaranteed when the local resource reservation was done on the driver of the MAC layer.

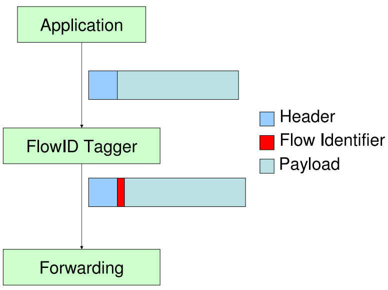


Fig. 3. Adding a flow identifier into data packets

B. OLSR

As stated before, the ad-hoc routing protocol used in WIDENS is OLSR [3]. The protocol has been modified in order to introduce QoS. In section IV we explain the QoS scheme used in WIDENS, and Section V-A describes the modifications introduced in OLSR to support the WIDENS QoS scheme.

C. Reservation Module

On the top of all modules described up to now, we have developed a module responsible for the management of reservations required by applications. This module implements an API (Table I) that allows applications to reserve networks resources to a given data flow and to undo this reservations when they are no longer needed. In order to avoid that resources are assigned to flow that don't exist anymore, besides offering to the application the possibility to explicitly release used resources, it constantly monitors applications that hold resources so that, if the data is ended, the reservation can be released.

After being called by the application, this module must somehow establish a reservation along the path towards the destination node. For this reason, it implements a lightweight resources reservation protocol designed by us and inspired on the RSVP protocol. Tightly coupled with this module, there is a CAC that checks the availability of resources in each node along the path.

TABLE I
WIDENS API DESCRIPTION

Primitive	Description
widens SetReservation	Allows the establishment of a new reservation.
widens SetReservation AndOpenSocket	Allows the establishment of a new reservation and opens a socket for transmitting data that will use this reservation
widens ReleaseReservation	Releases a pre-existent reservation
widens RegisterCallback	Registers a function to be called when an event occurs with any of the reservations made by the application

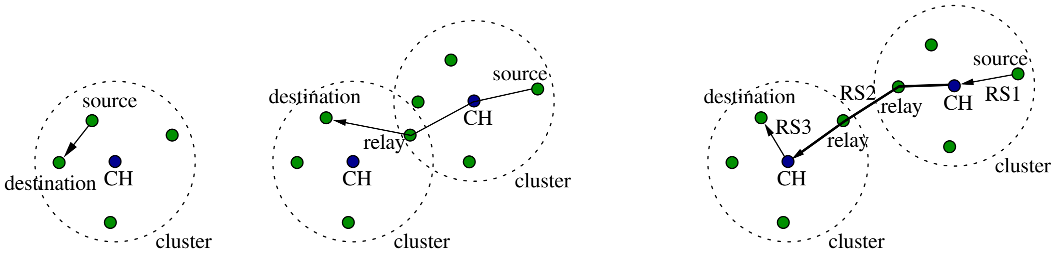
IV. QoS MANAGEMENT

In the rest of the paper we describe the QoS scheme used in WIDENS. As stated before, an RSVP-like scheme is used to provide QoS guarantees. The scheme takes into account the following characteristics of the QoS WIDENS MAC:

- Multirate: The mobile nodes can dynamically switch between several link rates. This allows the mobile nodes to select the transmission rate with better performance for every neighbor.
- Cluster organization: The nodes are organized in clusters. Adjacent clusters are separated using different channels.
- Intra-cluster transmissions: Transmissions inside a cluster (intra-cluster) are centralized and governed by a cluster-head (CH). Intra-cluster transmissions are contention-free, i.e. the CH delivers transmission-opportunities to the MNs. No RTS/CTS signaling is needed. However, nodes inside a cluster are not allowed to simultaneously transmit a packet (even if the destinations do not interfere each other).
- Inter-cluster transmissions: Inter cluster transmissions may occur in two different ways. The first one consists of using a relay node located in the intersection of adjacent clusters, by means of the centralized transmission previously described. The second one consists of using a backbone formed by the CHs and relays nodes. Transmissions in the backbone would be in a distributed manner.

In order to establish the route for a new connection requiring QoS guarantees, the L3 layer looks for a possible route that is able to accommodate the resources needed by the new connection (we shall refer to it as Call Admission Control, CAC). To do so, the following cases can occur:

- The source and the destination are in the same cluster (see Fig. 4(a)).
- The source and the destination are in different clusters. In this case, the route can be segmented into the different Route Sections (RSs) where resources have to be allocated. These RSs can be: intra-cluster (see Fig. 4(b)), and backbone RSs (see Fig. 4(c)). Since each RS uses independent resources, independent CAC must be applied to



(a) Intra–cluster. (b) Inter–cluster. (c) Inter–cluster using a backbone (RS2).

Fig. 4. Intra– and inter–cluster connections.

each RS, i.e. the node where a connection switches from a RS to another can be considered as the destination for the CAC in the previous section and the source for the CAC in the next RS.

In order to maintain as much isolation as possible between network (L3) and MAC (L2) layers, L3 is not aware of the cluster organization. In the following we describe the CAC algorithm designed to achieve all these goals.

A. Bandwidth QoS Constraint

WIDENS QoS management is based on a bandwidth reservation scheme, e.g. peak or sustainable bit rate allocation. More specifically, the goal of the QoS management is that: Given the maximum available bandwidth MAB_i for QoS traffic at each MN_i the following conditions are satisfied:

$$\text{QoS constraint: } MAB_i \geq 0, \forall i. \tag{1}$$

We shall refer to these conditions as the *QoS constraint*. The MAB_i values are dimensionless and can be interpreted as the percentage of free slots available at each MN_i. $MAB_i = 0$ means that no capacity is left for QoS connections at MN_i. $MAB_i < 0$ would mean that the capacity that MAB_i is sharing has been over-reserved. In the following we give the expressions for the MAB_i computation for intra-cluster and backbone transmissions.

1) Intra-Cluster Bandwidth QoS Constraint: Suppose that we want to use a percentage Q ($0 < Q \leq 1$) of the available capacity for QoS traffic inside a cluster. The parameter Q is dimensioned such that delays are acceptable for QoS connections.

Let $\mathcal{N}_i$ be the set of neighbor MNs of MN_i, i.e. $\{MN_j | j \in \mathcal{N}_i\}$ is the set of nodes in range with MN_i. We shall refer to the normalized QoS traffic generated or in transit at MN_i as the *bandwidth reservation* (x_i) at an MN_i. I.e. if r_{ij} is the amount of QoS traffic in bits per second (bps), sent from MN_i to MN_j at a link rate v_{ij} bps, then:

$$x_i = \sum_{j \in \mathcal{N}_i} r_{ij}/v_{ij} \tag{2}$$

Let $\mathcal{C}_i$ be the set of MNs transmitting inside cluster i. Since two nodes cannot simultaneously transmit inside the cluster, the MAB_i for all nodes inside cluster i is the same and it is given by:

$$MAB_i = Q - \sum_{j \in \mathcal{C}_i} x_j \tag{3}$$

2) Backbone Bandwidth QoS Constraint: The backbone is not organized in clusters, and the MN transmissions interfere only with the neighbor nodes. Thus, defining $\mathcal{N}_i^+$ as the set of MN_i and its neighbors i.e. $\{MN_i, MN_j | j \in \mathcal{N}_i\}$, the MAB_i is given by:

$$MAB_i = Q - \sum_{j \in \mathcal{N}_i^+} x_j \tag{4}$$

B. Reservation Approach

We define the *available bandwidth* AB_i to allocate new reservations at MN_i as:

$$AB_i = \min\{MAB_j\}, j \in \mathcal{N}_i^+ \tag{5}$$

Note that for an intra-cluster CAC the MAB and thus the AB of all the nodes is the same. However, for the backbone CAC, these quantities may be different.

We shall use the notation $MN_i \rightarrow MN_j$ to denote two consecutive MNs belonging to the path to be reserved for a new QoS connection. Suppose that a new QoS connection of r bps has to be established. We claim that if the path to be reserved does not follow unnecessary jumps (i.e. for all nodes MN_l belonging to the reserved path, it holds that if $\cdots MN_i \rightarrow MN_j \rightarrow MN_k \cdots$, then $MN_i, MN_k \in \mathcal{N}_j$, $MN_l \notin \mathcal{N}_j, \forall l \neq i, j, k$), then, the QoS constraint given by (1) is satisfied if the following CAC conditions hold:

- For the MN_i originating the new QoS connection:
  - If the destination (MN_j) is a neighbor of MN_i, then $AB_i \geq r/v_{ij}$.
  - If the destination is not a neighbor of MN_i and the connection follows the path $MN_i \rightarrow MN_j \rightarrow MN_k$, then $AB_i \geq r/v_{ij} + r/v_{jk}$.
- For all the transit MN_j (located along the path between the source and the destination):
  - If the destination (MN_k) is a neighbor of MN_j and the connection follows the path $MN_i \rightarrow MN_j \rightarrow MN_k$, then $AB_j \geq r/v_{ij} + r/v_{jk}$.
  - If the destination is not a neighbor of MN_j and the connection follows the path $MN_i \rightarrow MN_j \rightarrow MN_k \rightarrow MN_l$, then $AB_j \geq r/v_{ij} + r/v_{jk} + r/v_{kl}$.

Proof: Assume that the new QoS connection is accepted and use (3), (4) and (5) to verify that the QoS constraint is satisfied.

For instance, assume a backbone RS, thus, with the QoS constraint given by (4). Suppose the case when the new QoS connection of r bps is generated at MN_i and the destination MN_k is not one of its neighbors (see Fig. 5). Assume that the CAC accepts this connection along the path $MN_i \rightarrow MN_j \rightarrow MN_k$. Then, x_i and x_j will be respectively increased by r/v_{ij} and r/v_{jk}. Thus, the MAB of MN_i, MN_j and all their common neighbors will be decreased by $r/v_{ij} + r/v_{jk}$. Since $AB_i \geq r/v_{ij} + r/v_{jk}$ and $AB_j \geq r/v_{ij} + r/v_{jk}$ holds from the previous CAC conditions, equation (5) implies $MAB_l \geq 0, \forall l$.■

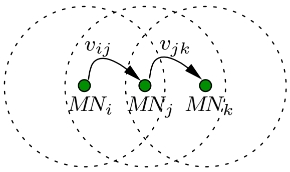


Fig. 5. Example of a connection generated at MN_i with destination MN_k.

1) Example: In this section we show an example illustrating the reservation scheme formerly described. Assume the backbone network shown in Figure 6. There are 6 MNs ($MN_a - MN_f$). Assume for simplicity that the links are symmetric ($v_{ij} = v_{ji}$). There is one QoS connection of $r_{af} = 1Mbps$ following the path $MN_A \rightarrow MN_b \rightarrow MN_e \rightarrow MN_f$. Assume also that the reserved capacity for QoS traffic is $Q = 0,8$.

The row x_i in Table II shows the bandwidth reservation that would be advertised by the MNs. Upon receiving theses values, the MNs would compute the MAB_i shown in the corresponding row of the table. For instance, MN_b would receive $x_a = 0,2$ and $x_e = 0,2$. Since $x_b = 0,1$ it will compute MAB_b = 0,3. Finally, upon receiving the MAB from their neighbors, the MNs would compute the AB_i given in the table.

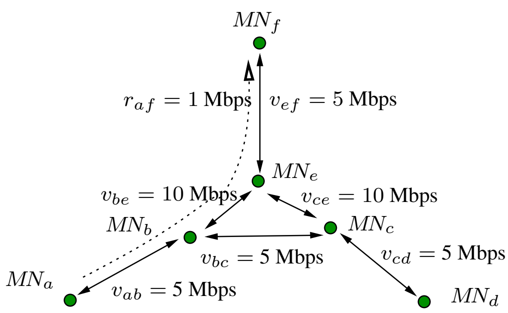


Fig. 6. Network topology

TABLE II
PARAMETERS COMPUTED BY THE NODES

	MN_a	MN_b	MN_c	MN_d	MN_d	MN_f
x_i	0,2	0,1	0	0	0,2	0
MAB_i	0,5	0,3	0,5	0,8	0,5	0,6
AB_i	0,3	0,3	0,3	0,5	0,3	0,5

V. IMPLEMENTATION

The CAC scheme described in the previous section requires that each MN_i computes the *available bandwidth* AB_i, which in turn requires the following quantities from their neighbors $\mathcal{N}_i$: (i) Their reservation (x_j, $j \in \mathcal{N}_i$), in order to compute MAB_i; (ii) Their maximum available bandwidth (MAB_j, $j \in \mathcal{N}_i$); and (iii) The link rate with each of its neighbors (v_{ij}).

Furthermore, as explained in Section IV, the CAC has to be applied to each RS. Remember that adjacent RSs use different channels in order to not interfere each other.

WIDENS L2 layer knows the ongoing reservations (and thus, the *bandwidth reservation* x_i), because L3 must communicate to L2 each new reservation (for the clusterhead to allocate resources). Furthermore, L2 layer uses a broadcast channel to exchanged L2 information with their neighbors. These L2 features are used in WIDENS in the QoS scheme implementation: L2 exchange neighboring information needed by the CAC, and, for each channel, L2 computes and communicates to L3 the maximum available bandwidth of the channel (MAB_i), and the link rate with each of its neighbors using this channel (v_{ij}). With this information, L3 computes AB_i and applies the CAC rules given in section IV-B.

A. CAC Integration in OLSR

In order to integrate the WIDENS QoS scheme, two main modifications has been done to the OLSR [3] routing protocol:

(i) OLSR TC messages are modified to advertise AB_i and v_{ij} next to advertising the MPR selectors. This way each node has knowledge of the network topology and the bandwidth available in the network.

(ii) In order to find a route that meets the QoS requirements, the OLSR route selection algorithm has been modified to find a shortest hop path that has enough bandwidth to meet these requirements. Since the TC messages also advertise AB_i and v_{ij} the originating node has enough information to decide if enough resources are available. This modification if further described in the following.

The default route selection algorithm from OLSR has been changed by the algorithm shown in pseudo code in figure 7. We will now apply this algorithm to a small example that will show how the CAC is implemented. Suppose N_i is the source and node N_l is the destination. The network topology is as follows:

$$N_i \rightarrow N_j \rightarrow N_k \rightarrow N_l$$

In step (1) the check $AB_i \geq r/v_{ij}$ is performed, regardless if N_j is the destination or not. If a neighbor is not the destination then the check $AB_i \geq r/v_{ij} + r/v_{jk}$ should be performed but since we do not know the destination of the 2nd hop this is not yet possible. If the first check succeeds the route is added. RAB_i (the remaining available bandwidth for MN_i) is set to $AB_i - r/v_{ij}$. RAB_j is set to $AB_j - r/v_{ij}$
In step (2) we will only add the route to N_k if the checks $RAB_i \geq r/v_{jk}$ and $RAB_j \geq r/v_{jk}$ succeed. If the CAC succeeds and N_k is the destination then a route has been found. If N_k is not the destination we set RAB_j to $RAB_j - r/v_{jk}$ and we set RAB_k to $AB_k - r/v_{jk}$. The partial route is then added to the table along with RAB_j and RAB_k.

```
 The following pseudo algorithm describes how the CAC is integrated into the OLSR route selection
algorithm:

 (1) Add all one hop neighbors registered as symmetric to the routing table with a hop-count of 1 and for
     which the CAC allows this route.
 (2) For each symmetric one-hop neighbor, add all two hop neighbors registered on that neighbor that
     has:
        - not already been added to the routing table.
        - a symmetric link to the neighbor.
        - been allowed by the CAC module.
     These Entries are added with a hop-count of two and next-hop as the current neighbor.  Set n equal to
     two.
 (3) Then, for every added node N in the routing table with hop-count n add all entries from the TC set
     where:
        - the originator in the TC entry is N
        - the destination has not already been added to the routing table
        - the CAC determined that enough resources are available among the route
     New entries are added with a hop count of n+1 and next-hop as the next-hop registered on N's routing
     entry.
 (4) Increase n with one and do step 3 over until there are no entries in the routing table with hop-count
     equal to n or if a route to the destination was found
```

Fig. 7. Integration of the CAC Algorithm in OLSR.

In step (3) $RAB_j \geq r/v_{kl}$ and $RAB_k \geq r/v_{kl}$ are checked to see if the flow can be allowed into the network. If N_l is not the destination but the CAC succeeds then RAB_k is set to $RAB_k - r/v_{kl}$ and RAB_l to $AB_l - r/v_{kl}$. Step (3) can then be repeated until a destination is found by letting N_k become N_j and N_l become N_k. In case N_l is the destination a route has been found and the algorithm will stop.

VI. Simulation Results

In this section we show some simulation results in order to illustrate the QoS scheme implemented in WIDENS. More results can be found in [8].

We have implemented the WIDENS QoS reservation scheme in the OLSR available in [9] for the network simulator [10]. We shall refer as QOLSR to our OLSR implementation. We wish to stress that this protocol has little in common with [11], only the idea of extending OLSR with QoS. We have not implemented the WIDENS MAC in ns, instead we have used the 802.11 MAC available in ns. Therefore, the simulation is clusterless, and MNs uses Equation 4 to compute the MAB. We have simulated the following scenario:

- MAC: 802.11 with RTS/CTS disabled and multi-rate on.
- Multi-rate parameters: for a distance less than 100 meters the rate is 11 Mbps; for a distance between 100 and 300 meters the rate is 2 Mbps.
- CBR connections sending packets of size 500 bytes and rate 32 kbps.
- The QoS constraint for CBR connections is $Q = 12.5\%$.
- 40 MNs randomly placed over a square 1000x1000 meters.
- MN coverage of 300 meters (i.e. any two MN at a distance $\leq$ 300 meter are in range).
- Each pair of nodes initiates a unidirectional call staggered 15s. Thus, 20 calls are initiated (20 x 32 = 640 kbps).
- The simulation time is 700 s, including a 100 s startup time giving OLSR the time to exchange routing information before starting the applications.
- The nodes don't move.

Using the following parameters for the OLSR protocol:

- HELLO_INTERVAL: 0.5 seconds
- TC_INTERVAL: 2 seconds
- NEIGHB_HOLD_TIME: 5 x HELLO_INTERVAL
- TOP_HOLD_TIME: 3 x TC_INTERVAL
- DUP_HOLD_TIME: 25 seconds

In the following we explain the results obtained using OLSR/QOLSR.

Figure 8 shows the evolution of the connections established with each protocol. Note that all connections are established with OLSR but only 9 with QOLSR (the others are blocked).

Figure 9 plots at each time t the maximum CBR Load (defined in section IV-A as *QoS Load Demand*) observed by the most congested node at this moment. This load is measured at each node counting the transmission time of MAC frames carrying CBR packets that are seen (transmitted or received) by the node (including the collisions). This figure validates that the QoS constraint is satisfied, i.e. the maximum CBR Load is $\leq$ 12.5%. This value is exceeded a bit among other reasons, because of the headers (the 500 bytes packet size does not include the IP header, neither the 802.11 header, thus, the occupancy at the MAC is in fact $12.5 \times 572/500 = 14.3\%$). Thus, we conclude from Fig. 9 that the QoS constraint is satisfied.

Fig. 9 also shows that, using OLSR, the MAC becomes congested at around 300 seconds (when only 14 of the 20 connections have started). This may be noticed by the fact that the CBR Load does not increase any more, although new connections are established. This is confirmed by Figs. 10 and 11. The first one depicts the maximum end-to-end delay of CBR packets, and the second one depicts the maximum percentage of packets lost by the connections, measured in intervals of 1.25 s (the transmission time of 10 packets). These figures shows us that QOLSR is not only successful in avoiding network congestion, but also in avoiding the packet losses and increased delays that occur when the network becomes congested. Compared to QOLSR, OLSR behaves much worse since it loses up to 80% of the packets at some instances.

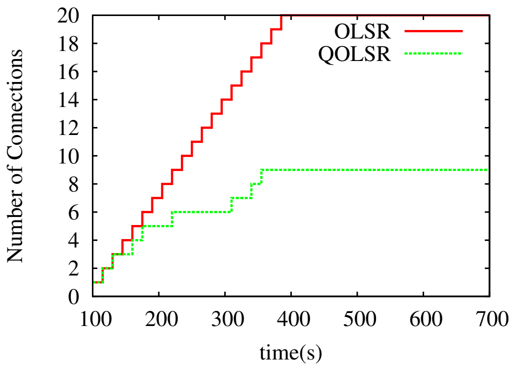


Fig. 8. Connection setup.

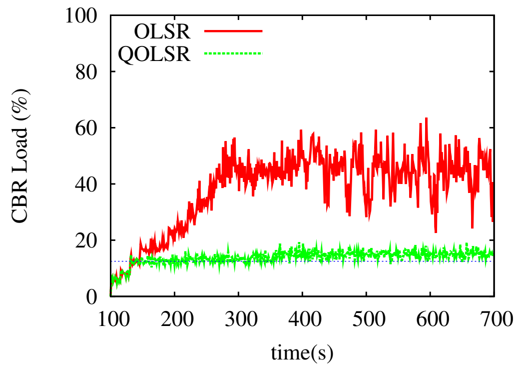


Fig. 9. Maximum occupancy.

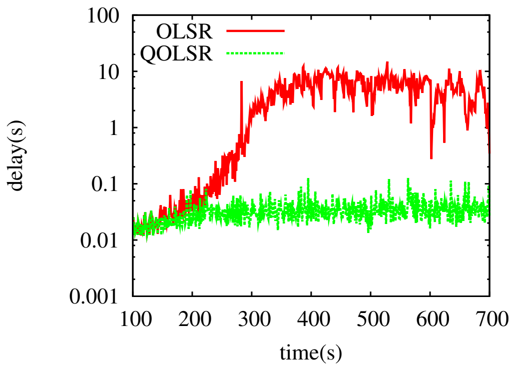


Fig. 10. Maximum delay.

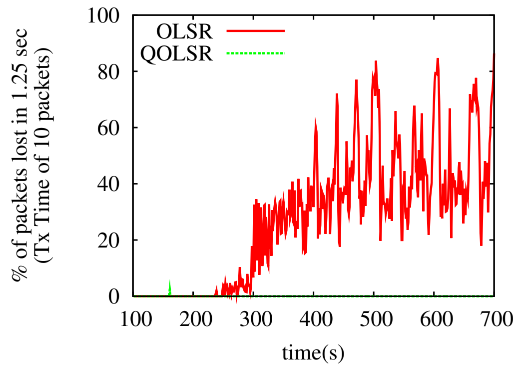


Fig. 11. Maximum loss.

VII. CONCLUSIONS

This paper presents an overview of the IST WIreless DEployable Network System (WIDENS) Project. WIDENS aims to define an easily deployable communication system to be used by emergency services and public safety in general. In order to meet these requirements, WIDENS implements a wireless ad-hoc network with Quality of Service (QoS) support.

The paper has been divided in two parts: First we have explained the architecture of the WIDENS terminodes, and we have introduced some implementation details of the different components at the PHY, MAC and network Layers.

In the second part of the paper we have explained the QoS scheme developed for WIDENS. This scheme is based on a bandwidth reservation scheme. We have described how the scheme has been integrated in the OLSR routing ad-hoc protocol used in WIDENS. Finally, we have presented some simulation results illustrating the QoS implementation.

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