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TRAFFIC ENGINEERING BASED ON EFFECTIVE ENVELOPE ALGORITHM ON NOVEL RESOURCE RESERVATION METHOD OVER MOBILE INTERNET PROTOCOL VERSION 6

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Abstract. *The first decade of the 21st century has seen tremendous improvements in mobile Internet and its technologies. The high traffic volume of services such as video conference and other real-time traffic applications are imposing a great challenge on networks. In the meantime, demand for the use of mobile devices in computation and communication such as smart phones, personal digital assistants, and mobile-enabled laptops has grown rapidly. These services have driven the demand for increasing and guaranteeing bandwidth requirements in the network. A direction of this paper is in the case of resource reservation protocol (RSVP) over mobile IPv6 networks. There are numbers of proposed solutions for RSVP and quality of service provision over mobile IPv6 networks, but most of them use advanced resource reservation. In this paper, we propose a mathematical model to determine maximum end-to-end delay bound through intermediate routers along the network. These bounds are sent back to the home agent for further processing. Once the home agent receives maximum end-to-end delay bounds, it calculates cumulative bound and compares this bound with the desired application end-to-end delay bound to make final decision on resource reservation. This approach improves network resource utilization.*

Keywords: Mobile IPv6, Resource reservation, Traffic engineering, Effective envelope, Resource utilization

1. **Introduction.** New applications such as video conference and voice over IP present many challenges to design of mobile networks. The mobile networks are constantly changing and the latest devices like smart phones, personal digital assistants, mobile enabled laptops such as Windows Mobile and the Windows Phone are truly able to deliver on any mobile broadband. As a study by ERICSON, one of top tier infrastructure suppliers for mobile networks, shown in July 2010, there are approximately five billions cell phone lines in the globe. This survey estimates 3.4 billion smart phone users in 2015. Thus, the Internet service providers must deliver a high quality of service to the customers. The key factors on quality of services can be considered as follows:

- Bandwidth optimization.
- Improvement of resource utilization.

Besides, mobile networks should be content-aware and constantly optimized for real-time applications. Mobile network should be able to route different types of contents to their customers and be able to realize types of contents requested. The growing demand for real-time applications in mobile networks has resulted in more and more active researches to be done on scalability, compatibility packet routing with minimal changes to the network-infrastructure.

2. **Problem Statement and Preliminaries.** Most of researches that have been done in mobile IPv6 networks are focusing on the efficiency of the network. The way in which resources are allocated and managed [1, 2] is an important issue. For instance, we need to avoid advanced resource reservation. It results in a need to propose an adequate approach to guarantee resource reservation through intermediate routers for real-time applications that leads to improvement in resource utilization. This leads to, more resources for the other connections to be accessible.

A direction of this paper is in the case of resource reservation protocol (RSVP) in mobile IPv6 networks. There are numbers of proposed solutions for RSVP and quality of service provision over mobile IPv6 networks, but most of them use advanced resource reservation. This leads to resources reservation on the points of network that mobile node may not visit.

Authors in [5-7] proposed a mobile RSVP. In this model a mobile node can make advanced resource reservation along the data flow paths to and from the locations it may visit. The mobile node can be a sender or receiver or both of them simultaneously. In this model a mobile node can make advanced resource reservations from a set of locations, called mobility specification (MSPEC). MSPEC is set to the locations that mobile node visit in a connection. When a mobile node moves to a new foreign network, it searches all of the proxy agents in its neighborhood and then updates MSPEC by using proxy discovery protocol [6]. The remote proxy agents will make advance reservation on behalf of the mobile node. It will establish an active reservation along the path from the sender to the mobile node and passive reservation to the locations where indicated in its MSPEC. The problem of Mobile RSVP is advanced determination of the set of locations that mobile node visit. It is difficult to accurately determine this set of locations in advance for a mobile node [9-12]. RSVP approach makes advanced resource reservation in all neighbors subnets. It results in degrading of resource utilization in points of network that mobile node may not visit there.

Hierarchical MRSVP (HMSRVP) approach [11] makes a fewer advanced resource reservation. HMRSVP makes advanced resource reservation for a mobile node only when the mobile node is close to overlap area of the boundary cells [12] between two regions based on mobile IPv6 regional registration [13]. Although this approach reduces advance resource reservation in the neighbors but it is still using this mechanism.

An RSVP extension has been presented in the [14] to support real-time applications in hierarchical mobile IPv6 (HMIPv6). In this approach a QoS agent (QA) is proposed in intra-site mobility, to handle RSVP QoS update message and provide the advanced reservation model for real-time application. When the MN moves into the boundary of a site, QA should inform another QA to set up the QoS path in advance.

Therefore, it is necessary to propose approaches to reduce resource utilization along the network. Authors in [1, 2] proposed an adaptive per-flow traffic engineering approach, i.e., local state fair share bandwidth algorithm (LSFSB) to utilize resources for additional algorithm. This approach is designed to fit small networks using DiffServ services [17-19]. Decision made at the edge routers of the network. Multiple disjoint label switched paths are pre-configured between each pair of edge routers. Between edge pair of edge routers, traffics for every class of service are sent on every path between those edge routers. The characteristic of the transmission are measured at the edge router and it sends the results back to ingress edge router at the beginning of the path. Edge routers make decisions based on this information and pick a suitable path for newly admitted traffic flows. Result might be total amount of bandwidth that can be transferred over this path, or set of candidate path with minimum path delay. Three different metrics are considered for making final decision on traffic engineering: the path delay, the path loss, and bandwidth reserved by low priority traffics. As results in [2] show, it has equal or a bit better performance in comparison with shortest path algorithm to utilize resources between two edge routers.

The objective of this research is to improve the network resource utilization along the network. This is done by proposing a mathematical model to determine the maximum bound of end-to-end delay through the intermediate routers.

3. **Traffic Engineering.** To enhance resource reservation along the guaranteed path, and also to improve the network resource utilization, traffic engineering is proposed. Traffic engineering is based on effective envelope [18] algorithm. To decrease the network overhead and improve the network performance. The components of traffic engineering include three major entities which are classifier, scheduler and effective envelope modules.

3.1. **Classifier and scheduling algorithm implemented in cross-layer design.** According to Figure 1, the arrivals are classified and then inserted to a buffer. Classifier classifies packets to QoS classes and scheduler determines the order of output. In the case of real-time applications, priority queuing scheduling algorithm [19] is used for scheduling traffic in scheduler because application is running on the MN or CN are real-time and time sensitive. Then, output of the classifier and scheduler enters to the effective envelope module. This module allows a fraction of arrivals to exceed the required QoS. The effective envelope is based on statistical network service that allows a fraction of traffic to not meet its QoS requirements. It causes improvement in network resource utilization. There are two types of performance guarantees in QoS networks, deterministic service and statistical service. A deterministic service guarantees that every packets from a flow satisfy worst case end-to-end delay bound and no packet drop in the network, while, a statistical service makes probability service guarantees by this module allows a fraction of arrival to exceed quality of service. Deterministic bounds are easier to determine while they lead to inefficiency in resource management. However, statistical bounds lead to improvement in link utilization and network gain. In general, resources required to service N flows with statistical bounds are much less than the resources required to service N flows in the case of deterministic bounds.

The intermediate routers along the guaranteed path make local reservations with a tight bound based on local calculated maximum end-to-end delay values. Moreover, this bound from each intermediate router is recorded in the message as it crosses towards the guaranteed path. Whenever end node receives reservation request, it piggybacks these bound to the home agent with the next message. Once the home agent receives maximum end-to-end delay bounds, it calculates cumulative bound and compares this bound with

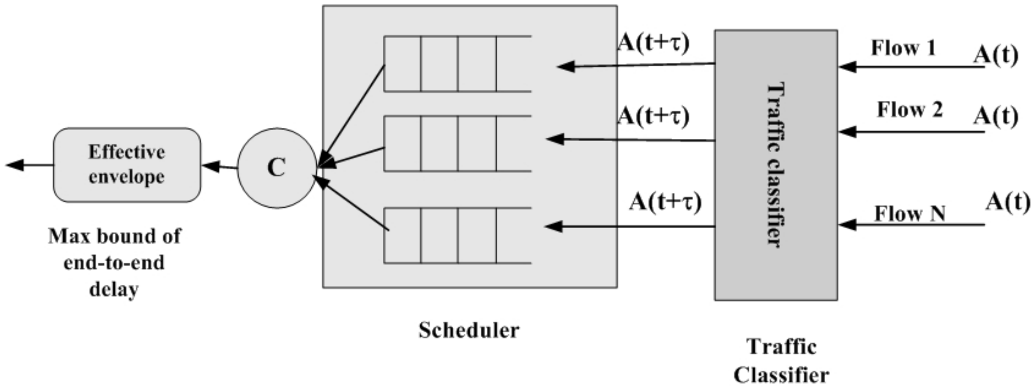


Figure 1. Traffic engineering

the desired application end-to-end delay bound, if cumulative bound is less than desired application bound, it sends a pathtear message to relax resources and their bounds along the guaranteed path because resources are available; otherwise, those fraction of traffic which have end-to-end delay more than application end-to-end desired bound are assigned best effort service.

ALGORITHM 1 explains classifier and scheduler algorithm.

Listing 1. /** ALGORITHM 1: Classifier and Scheduler Algorithm

```
void acb_prio (OP_SIM_CONTEXT_ARG_OPT){
/* A new packet has arrived, acquire it
 pkptr = op_pk_get (op_intrpt_strm ());
/* Insert the new packet according to priority in subqueue 0
 (op_subq_pk_insert (0, pkptr, OPC_QPOS_PRIO) != OPC_QINS_OK) {
/*  IF the insertion failed THEN discard the packet
        op_pk_destroy (pkptr);
        }
/* A request has been made to access the queue
/* IF queue is not busy THEN
 if (!op_subq_empty (0))  {
/* Access the high priority packet in the subqueue
  pkptr = op_subq_pk_remove (0, OPC_QPOS_HEAD);
/*  Forward it to the destination without causing a stream interrupt
   op_pk_send_quiet (pkptr, 0);
    }
```

3.2. **Determination of the maximum end-to-end delay.** Details of "effective envelope" module [18] appear below. We propose a mathematical model to determine the maximum bound of end-to-end delay based on effective envelope approach [18]. This model is applicable on established guaranteed path [20] between the MN and CN.

A model for QoS provisioning not only has to take into account the conformance of guaranteed bounds on services, it also should consider factors involving the scalability of the deployed QoS solution. By ignoring a percentage of arriving traffics to violate its quality of service guarantees we assume that,

Definition 3.1. Pr$\{$*traffic violating QoS guarantees*$\} < \epsilon$, *where* ϵ *is the maximum probability of QoS violations.*

The arrival of packets is considered to be a random process in which a set of C packets that consist of q classes are allowed into the network. Consider C_q to be the subsets of packets from class q and the random variable $A_j(t_1, t_1)$ to represent the arrival traffic from flow j in the time interval (t_1, t_2). Then, considering A_{cq} to denote the aggregate arrivals from the set C corresponding to the class q, we have the following relation,

$$A_{cq} = \sum_{j \in C_q} A_j(t, t + \tau) \tag{1}$$

We assume that traffic flows are characterized as follows: a) Traffic arrivals A_{cq} are regulated by a $A^*{}_{cq}$ as

$$A_{cq}(t, t + \tau) \le A^*{}_{cq} \quad \forall t \ge 0, \quad \forall \tau \ge 0 \tag{2}$$

b) The A_{cq} is a stationary random variable, in other work:

$$\Pr(A_{cq}(t, t + \tau) \le x) = \Pr(A_{cq}(t', t' + \tau) \le x) \tag{3}$$

The input arrival can be considered as following equation, δ_{cq} is a burst size parameter:

$$A_{cq}(\tau) = \delta_{cq} + P_{cq}\tau \tag{4}$$

The determination of upper bounds on reserved capacity at each node along a path for each class is based upon the concept of an effective envelope. A local effective envelope for $A_{cq}(t, t+\tau)$ is a function $G_{cq}(0;\epsilon)$ [21] and [18] which satisfies the inequality:

$$\Pr\{A_{cq}(t, t+\tau) \leq G_{cq}(\tau;\epsilon)\} \geq 1-\epsilon \quad \forall t, \tau \geq 0 \tag{5}$$

In other words, it provides a bound for the arriving traffics $A_{cq}(t, t+\tau)$ for any specific time arrival of length of τ.

$$G_{cq}(\tau;\epsilon) = N_q \min(x, {A^*}_{cq}(\tau)) \quad \forall \tau \geq 0 \tag{6}$$

where

$${A^*}_{cq}(\tau) = \min\{P_{cq}\tau, \delta_{cq} + p_{cq}\tau\} \tag{7}$$

It is clear that $P_{cq} \geq p_{cq}$ where P_{cq}, and p_{cq} are the peak and average traffic rate respectively, and $sigma_{(cq)}$ is burst size parameter.

$$p_{cq} = \lim_{\tau\to\infty} \frac{A_{cq}(t, t+\tau)}{\tau} \tag{8}$$

We define $\hat{\tau}$ as a function of class q at time t as below:

$$\hat{\tau} = \inf\{x \geq 0 | A^{q,t}(t-x, t) \leq x\} \tag{9}$$

In time interval $[t-\hat{\tau}, t)$ the scheduler is continuously transmitting traffic. Besides, class q arrival at time t will leave the scheduler at time $t+\delta$ if $\delta \geq 0$

$$\delta = \inf\left\{\tau_{out} | A^{q,t}(t-\hat{\tau}, t+\tau_{out}) \leq \hat{\tau} + \tau_{out}\right\} \tag{10}$$

Class q arrival does not violate its delay bound d_{out} if and only if:

$$\forall\hat{\tau}\exists\tau_{out} \leq d_q, \quad \text{i.e.,} \quad A^{q,t}(t-\hat{\tau}, t+\tau_{out}) \leq \hat{\tau} + \tau_{out} \tag{11}$$

The arrival from class q at time t does not have a violation if d_q is selected such that:

$$\sup_{\hat{\tau}} \left\{\sum A^{q,t}(t-\hat{\tau}, t+d_q)\right\} \leq d_q \tag{12}$$

The probability that the arrival from time t experience a deadline violation is less than ϵ if d_q is selected such that

$$\Pr\left[\left\{\sup_{\tau>0} \sum A_{cq}(t-\hat{\tau}, t+\bar{\tau}) - \hat{\tau}\right\} \leq d_q\right] \geq 1-\epsilon \quad -\hat{\tau} \leq \bar{\tau} \leq d_q \tag{13}$$

Using a finite buffer size B_{mq} at each node m for class q, the arrivals to a full buffer will be dropped while the arrivals that do get into the buffer will be served at a minimal rate denoted by C_{mq}. If we assume that the delay bounds at node m for class q is denoted by d_{mq}, the problem of QoS provisioning results in the allocation of the network capacity C_{mq} which would be the smallest number satisfying the following inequality:

$$\sup_{\tau>0}(G_{mq}(\tau;\epsilon) - C_{mq}\tau) \leq C_{mq}d_{mq} \tag{14}$$

$$B_{mq} = C_{mq}d_{mq} \tag{15}$$

Furthermore, the rate at which traffic would be dropped at node m due to a full buffer is bounded by:

$$\sum \epsilon \left\{\sup_{\tau>0}\left({A^*}_{c_{mq}} - G_{mq}(\tau)\right)\right\} \tag{16}$$

While it is possible to reduce the statistical bounds on end-to-end delay and packet drop rates for packets of class q along a path p based on the bounds from Equations (4) through to (16), a deterministic bound [22] on these metrics are more informative and are presented below. Assuming a link capacity of L_{c_i} at hop i along a path P consisting of n hops with $L_{\max}$ being the maximum transmission unit along the path with $prop_i$ and

r being the service rate at node i and the requested bandwidth respectively, we have the following end-to-end delay bound:

$$E2E_{\max_{bound}} = \left(\frac{\delta + nL_{\max}}{r}\right) + \sum_{i=1}^{n}\left(\frac{L_{\max}}{Lc_i} + prop_i\right) \tag{17}$$

The intermediate routers along the guaranteed path make local reservations with a tight bound based on local calculated maximum end-to-end delay values, Equation (17). Moreover, cumulative bound is recorded in the message as it crosses towards the guaranteed path. For this purpose, each traffic flows goes through the guaranteed path and the intermediate routers along the path make local reservation with a tight bound on the local end-to-end delay values. Then, each intermediate router sends local end-to-end delay bound to the home agent. Once home agent receives cumulative end-to-end delay bound, it compares this bound with desired application bound, if cumulative bound is less than application desired bound, it sends a pathtear message to relax resources and their bounds along the guaranteed path because resources are available; otherwise, those fraction of traffic which have end-to-end delay more than desired bound are assigned best effort service [23, 24]. It results in improving the resource utilization.

3.3. **Operation of effective envelope module.** The operation of collecting maximum bound of the end-to-end delay in each intermediate router proceeds as follows. After creation of guaranteed path, by receiving the real-time packet, home agent sends this message including traffic characteristics $(\delta_{cq}, p_{cq}, P_{cq})$, where δ_{cq} is the burst size, p_{cq} is the average traffic rate, and P_{cq} is the peak rate. This message travels over the intermediate routers belong to the guaranteed path. At each intermediate router ith, the maximum end-to-end delay bound based on Equation (17) that specific router i can guarantee is computed and added to the D_{cq}, which is cumulative delay bound. In the home agent, this bound would be calculated, if the cumulative delay Dj exceeds the desired end-to-end delay bound, then a release message is sent to the routers through the guaranteed path to release the bound. Otherwise, the intermediate routers reserve the resources based on their local computed bound. Then, those fraction of traffic that have end-to-end delay more than desired bound are assigned best effort service. The cumulative bound is given by:

$$D_{cq} = \sum_{i=1}^{n} \max_{bound}/n + 0.1 \tag{18}$$

Therefore, cumulative bound is computed by sum of maximum end-to-end delay bounds divide by number of intermediate router plus 0.1 which we count home agent as one separate entity.

4. **Fault Tolerant and Path Recovery.** To failure protection that could occur in link or intermediate routers we use bypass route. In this case whenever link or intermediate router failure occur, guaranteed path redirects traffic via bypass route to avoid drop packet. For instance, link between node "D" and "E" goes down as shown in Figure 2. To avoid packet loss in that case, we suggest bypass route to packet forwarding in the different route until the failed link go back to the network. As is shown in Figure 2, there are various paths for data transmission. Bypass route will be used in the simulation section.

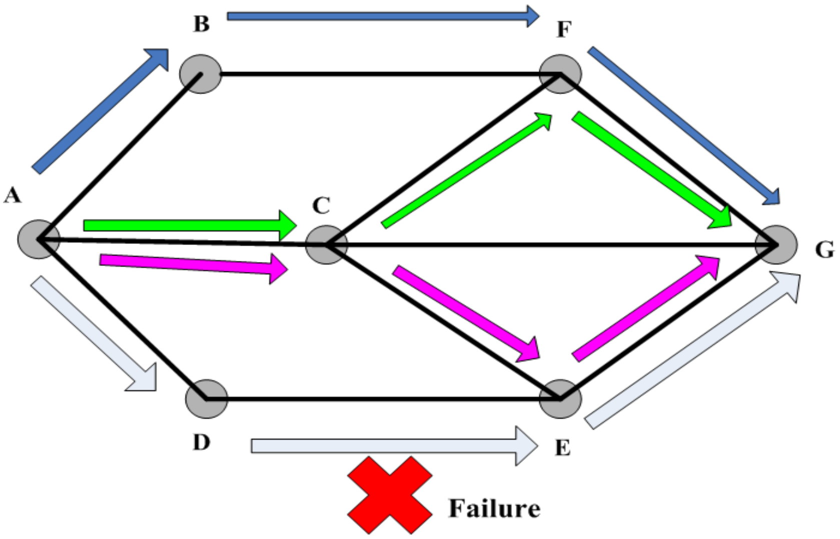


FIGURE 2. Fault tolerant

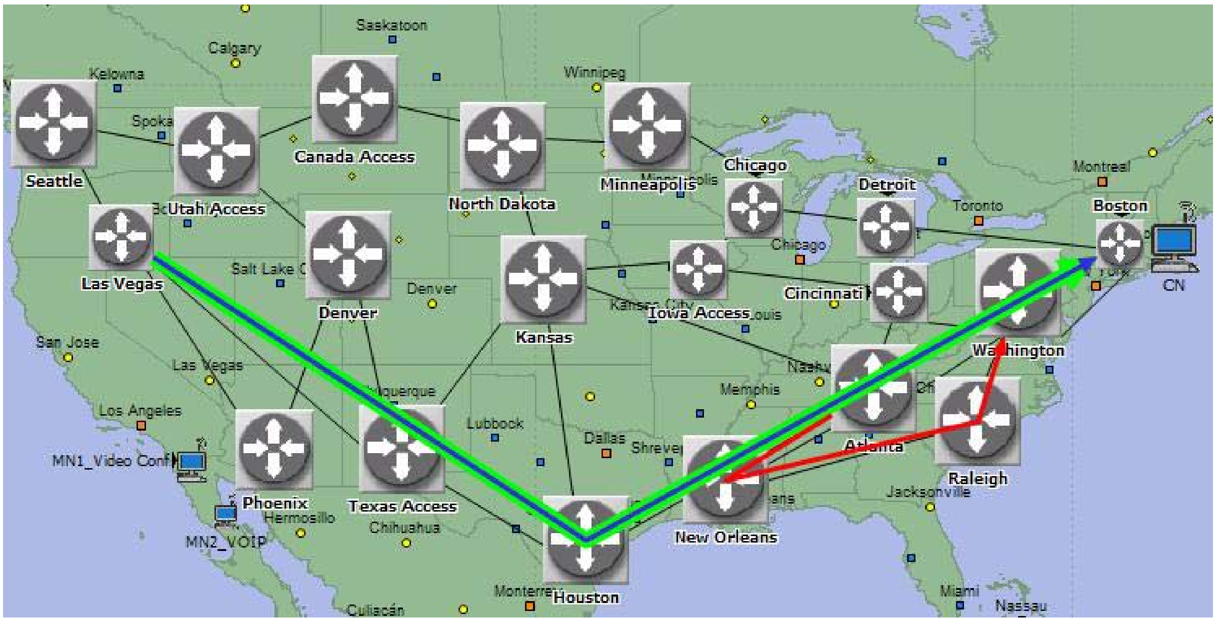


FIGURE 3. Network environment

5. **Practical Examples and Simulation Results.** Simulations are conducted using OPNET IT Guru academic edition 9.1 [25]. The simulation environment consisted of one correspondent node (in Boston), one home agent, i.e., Las Vegas router and intermediate routers in the core network, and two mobile nodes connected to the Phoenix router. Mobile nodes are currently moved to a new foreign network, i.e., Phoenix router, while, their home agent is Las Vegas router. The simulation period is 1200 seconds. Simulation parameters are: link capacity: 10 Mbps, maximum transmission unit is 5600 bytes, intermediate routers service rates are different from is 4800 to 9600 bps.

According to Figure 3, there are two active guaranteed paths between the home agent, i.e., Las Vegas router and the access router in a the correspondent node's network, i.e., Boston router. First and second guaranteed path are from Las Vegas router to Houston router and then to Boston router, while both of them cross from Texas Access, Houston, New Orleans, Atlanta, and Washington routers. In other words, Texas Access, Houston, New Orleans, Atlanta and Washington are intermediate routers along the guaranteed path. Besides, we consider an path recovery (red path in Figure 3) to failure protection by bypass route. In the event of a link or router failure, this bypass route redirects traffic to avoid packet drop. During a period of 300 milliseconds, the link between two intermediate router, i.e., "Houston" and "Washington" fail and then the packet are redirected from bypass route that is formed between these two routers. Transmission data rate in the core network is 155.52 Mbps. Link between "New Orleans" and "Washington" fails at time 700 seconds to evaluate fault tolerant and path recover. According to our configuration transmission traffics from the guaranteed path (green path in Figure 3) will not be redirected to the bypass route, while, transmission traffics from the guaranteed path (blue path in Figure 3) would be redirected to the bypass route in the time of link or router failure.

Furthermore, one of mobile nodes (MN1_Video Conf) is running a video conference application and other one, i.e., MN2_VOIP is running a VOIP application. Both of applications are real-time and delay sensitive. Table 1 illustrates MN1_Video Conf's attributes. We set type of service to reserved that requires high priority, low latency, low jitter, and reserved bandwidth.

Table 1. MN1_Video conference attributes

Parameters	Value	
Frame size	$512 * 512$ (pixels)	
Type of service	Reserved	

Table 2 illustrates MN2_VOIP's attributes. We set type of service to reserved that requires high priority, low latency, low jitter and reserved bandwidth.

Table 2. MN2_VOIP attributes

Parameters	Value	
Running Application running	VOIP	
Encoder	G.711	
Type of service	Reserved	

Table 3 illustrates class of service values ranges related to class of service from 0 (best effort- low priority) to 7 (network control- high priority). Besides, encoder is used in our network topology is G.711 that also known as pulse code modulation (PCM). It is a PCM of voice frequencies on a 64 kbps channel.

Simulation parameters are listed in Table 4.

Table 3. Class of service

Class of Service	Code	
Best Effort	000	
Background	001	
Standard	010	
Excellent Effort	011	
Controlled load applications	100	
Interactive Multimedia	101	
Interactive Voice	110	
Networking Control	111	

Table 4. Simulation parameters

Parameters	Value	
Physical Characteristic	Frequency Hoping	
Data Rate (*bps*)	11Mbps	
Transmit Power	0.009W	
Packet Reception − *power threshold*	-95	
Short Retry Limit	7	
Long Retry Limit	4	
Aaccess point beacon Interval (*Secs*)	0.002	
Maximum Receive lifetime (*Secs*)	0.5	
Buffer Size	25600	

6. Simulation of Traffic Engineering.

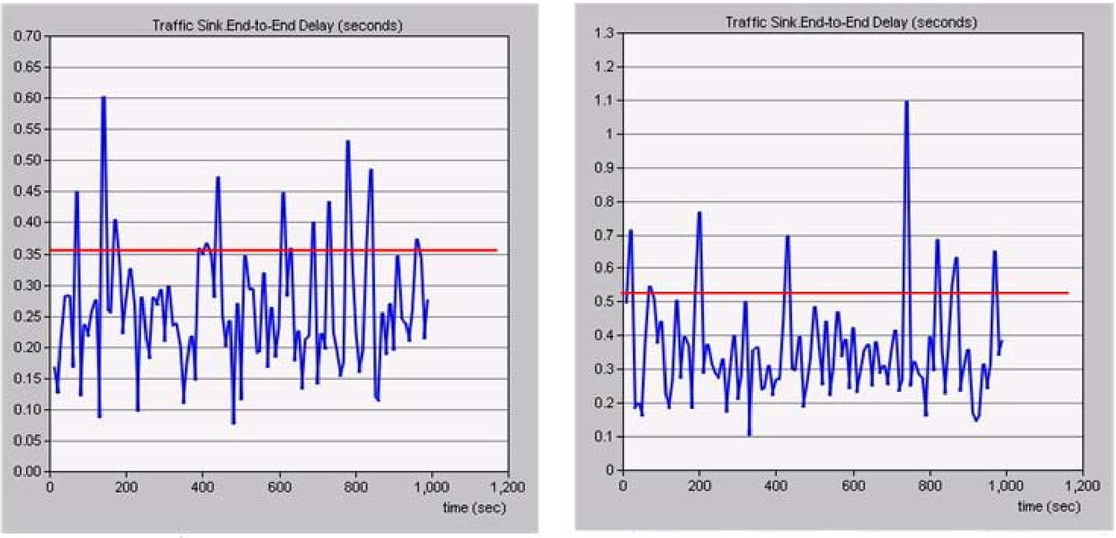
In this subsection, maximum end-to-end delay bounds in five intermediate routers, i.e., Texas Access, Houston, New Orleans, Atlanta and Washington are calculated. Besides, cumulative bound and desired application end-to-end delay bound is compared based on effective envelope algorithm.

From Figure 4(a), maximum end-to-end delay calculated according to Equation (17) is 0.36 seconds. Therefore, Texas Access router as an intermediate router along the guaranteed path makes local reservations based on this bound. Besides, it sends this bound by path message to home agent for the purpose of cumulative bound. From Figure 4(b), maximum end-to-end delay calculated according to Equation (17) is 0.54 seconds. Therefore, Houston router as an intermediate router along the guaranteed path makes local reservations based on this bound. Besides, it sends this bound by path message to home agent for the purpose of cumulative bound. From Figure 4(c), maximum end-to-end delay calculated according to Equation (17) is 0.35 seconds. Therefore, New Orleans router as an intermediate router along the guaranteed path makes local reservations based on this bound. Besides, it sends this bound by path message to home agent for the purpose of cumulative bound. From Figure 4(d), maximum end-to-end delay calculated according to Equation (17) is 0.34 seconds. Therefore, Atlanta router as an intermediate router along the guaranteed path makes local reservations based on this bound. Besides, it sends this bound by path message to home agent for the purpose of cumulative bound. From Figure 4(e), maximum end-to-end delay calculated according to Equation (17) is 0.28 seconds. Therefore, Washington router as an intermediate router along the guaranteed path makes local reservations based on this bound. Besides, it sends this bound by path message to home agent for the purpose of cumulative bound.

Once home agent receives end-to-end delay bounds, it calculates cumulative bound and compares it with desired bound. If cumulative bound is less than desired bound, it sends a pathtear message to relax resources and their bounds along the guaranteed path because resources are available; otherwise, those fraction of traffic which have end-to-end delay more than desired bound are assigned best effort service. Cumulative bound in Figure 5 is 0.48 seconds and application desired end-to-end delay bound is 0.58 seconds. Because application desired end-to-end delay bound is less than cumulative bound, those fraction of traffic which have end-to-end delay more than application desired end-to-end delay bound are assigned best effort service. These traffics include short transmission time but due to they are real-time applications; therefore, those are assigned best effort service.

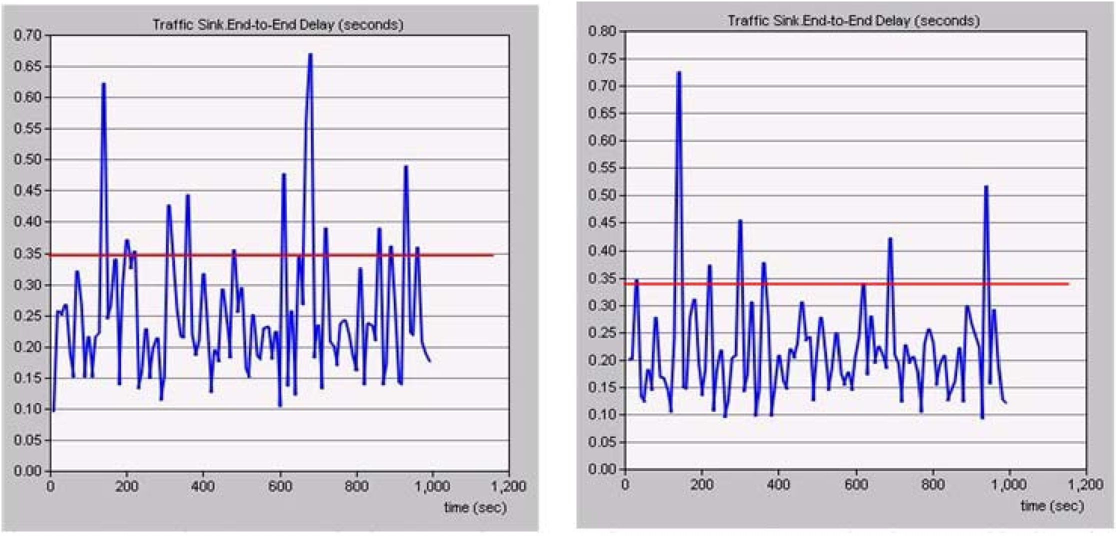
6.1. Evaluation of traffic engineering.

According to effective envelope algorithm and statistical services, we use traffic engineering to improve link utilization. In the presented method, each intermediate router determines its maximum end-to-end delay bound and



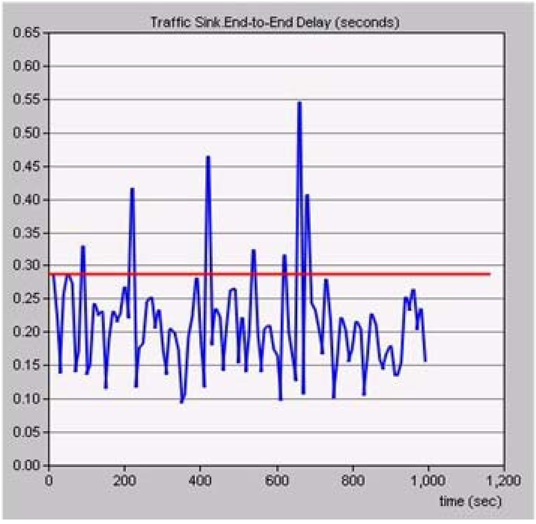
(a) Maximum end-to-end delay bound in the Texas access

(b) Maximum end-to-end delay bound in the Houston



(c) Maximum end-to-end delay bound in the New Orleans

(d) Maximum end-to-end delay bound in the Atlanta



(e) Maximum end-to-end delay bound in the Washington

FIGURE 4. Maximum end-to-end delay bound based on effective envelope in intermediate routers – red line

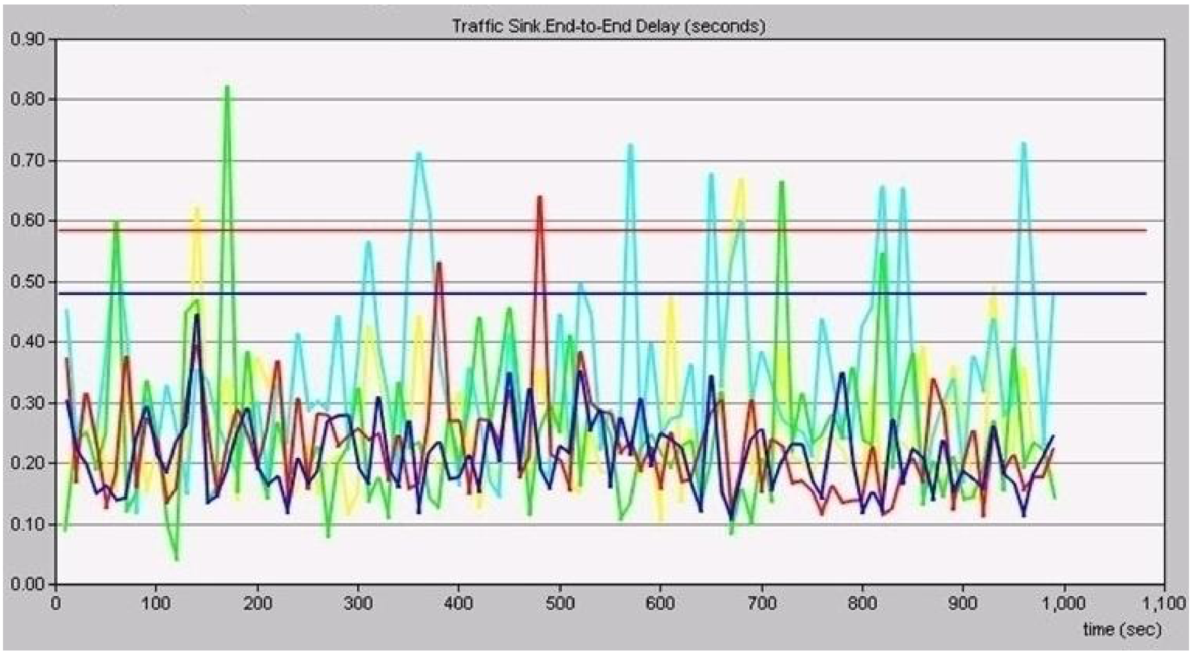


Figure 5. Red line: cumulative end-to-end delay bound, blue line: desired bound

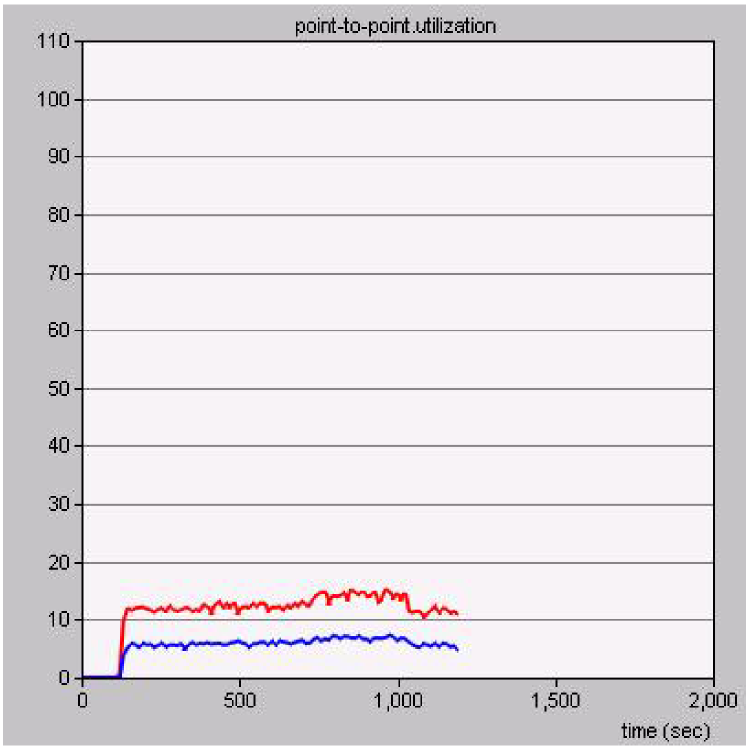


Figure 6. Link utilization based on traffic engineering, intermediate router is New Orleans, blue: presented approach, red: LSFSB approach

makes local reservation based on this bound and sends back this bound to the home agent for decision on link utilization.

From Figure 6 link utilization when effective envelope module is used in New Orleans router which is located over guaranteed path results approximately 30% in comparison of when local state fair share bandwidth algorithm (LSFSB) [1, 2] is used in this router.

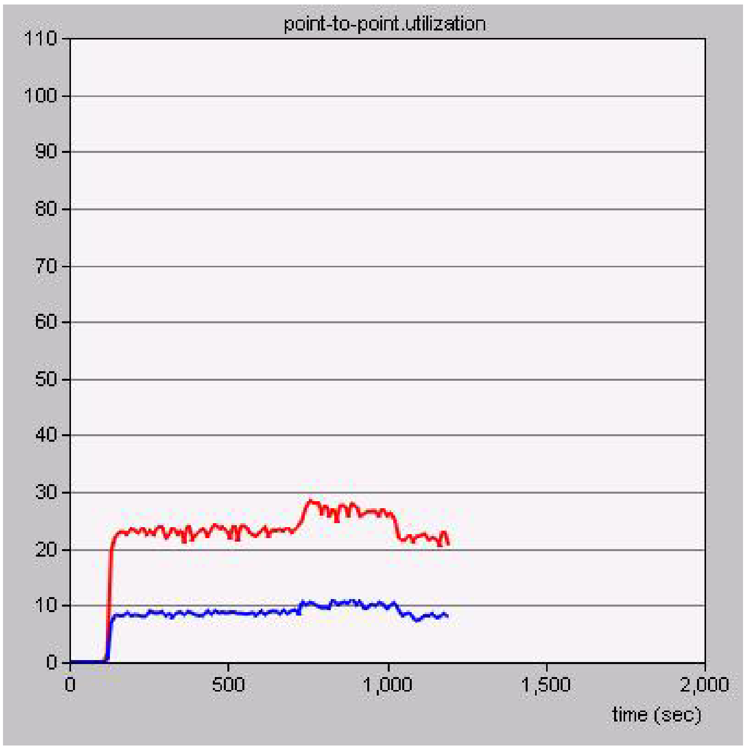


FIGURE 7. Link utilization based on traffic engineering, intermediate router is Houston, blue: presented approach, red: LSFSB approach

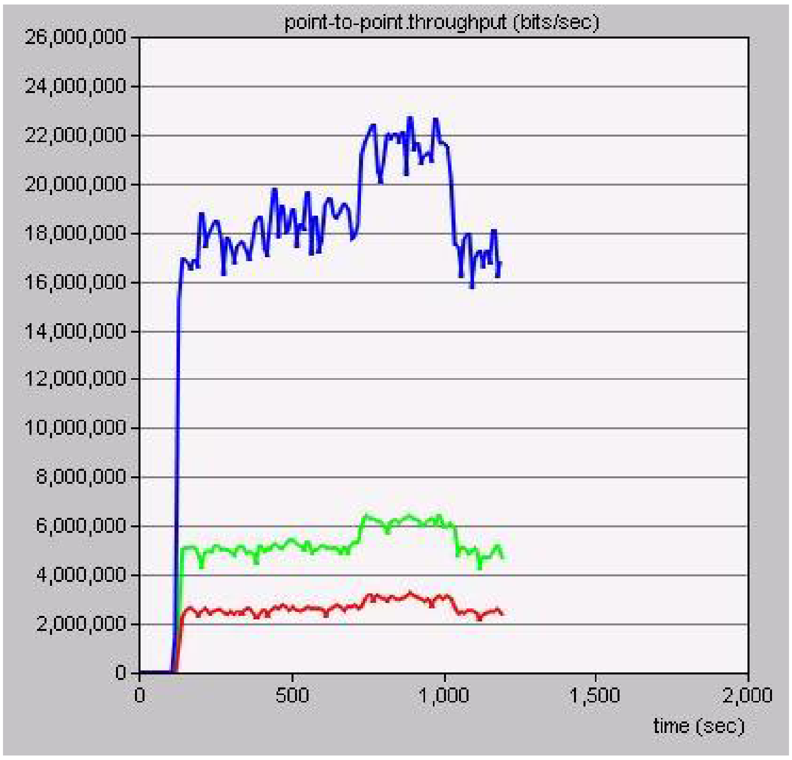


FIGURE 8. Link throughput from home agent to the correspondent node – blue curve: presented approach, green curve: RSVP extension, red curve: HMRSVP

There is a timing gap in the beginning of link utilization, the reason is it takes some time to HA receives traffic from the end node.

From Figure 7 link utilization when traffic engineering is used in Houston router which is located over guaranteed path results approximately 25% in comparison of when local state fair share bandwidth algorithm (LSFSB) [1, 2] is used in this router. The number of link utilization is increased between time 700 to 1000 seconds in each approaches illustrated in Figures 6 and 7. The reason is, as we mentioned earlier, link between Atlanta and Washington fails at time 700 seconds and back to the network at 1000 seconds. During this period of time traffics are diverted to created bypass route.

6.2. **Evaluation of link throughput.** We evaluate link throughput along the guaranteed path in the ROMA approach [20] which is using traffic engineering in comparison with two recent approaches, i.e., HMRSVP (2003) and RSVP extension (2007). This helps us to find an overview of average rate of successful traffic delivery over guaranteed path. From Figure 8, results show that by doing traffic engineering and link/path recovery on guaranteed path, there is a great rise in link throughput along the guaranteed path across the mobile IPv6 network. The blue curve in Figure 8, which is presented method,

Table 5. Statistic data – time (seconds), end-to-end delay (seconds)

	Texas Access	Houston	New Orlando	Atlanta
Time	End-to-end Delay	End-to-end Delay	End-to-end Delay	End-to-end Delay
0.0	0.24302	0.278784774341	0.258825970275	0.718745979245
12	0.184084056813	0.297387158562	0.253896335814	0.376111089628
24	0.256836662971	0.224739462256	0.378803437153	0.681431077093
36	0.301841949794	0.263376384288	0.410712144507	0.281800867863
48	0.159882014588	0.374829905123	0.771386539473	0.299604808765
60	0.295769308279	0.237284601067	0.764432673789	0.274081380778
72	0.51154058481	0.519078792026	0.286090012902	1.58138329286
84	0.135213092591	0.311122631289	0.178843082378	1.5662583054
96	0.339563068067	0.300090926457	0.162610860462	0.982196517934
108	0.282787219158	0.350818034521	0.206980089782	1.33584851415
120	0.245192663891	0.309879343371	0.226080758156	0.274831475181
132	0.240369112829	0.274402053874	0.420708407171	0.265320416691
144	0.421671904101	0.200566577047	0.254587878437	0.272650824426
156	0.179853333333	0.233703860925	0.234975160372	0.820715008098
168	0.256196667153	0.222261268337	0.217171338338	0.127546359545
180	0.214700307083	0.45302167973	0.364913328268	0.428473568587
192	0.153736	0.193437930349	0.299404902345	0.220971891184
204	0.20561	0.278392080958	0.360416233039	0.296439350606
216	0.170896221175	0.310752837284	0.284871094679	0.150612683288
228	0.28068474141	0.240356435903	0.195173386623	0.49746122331
240	0.256445590442	0.326420163887	0.168772201699	1.02248787951
252	0.16682	0.252379589297	0.270850079611	0.410545506148
264	0.877670119992	0.504132177796	0.272414119104	0.379740365383
276	0.254380050036	0.219853823685	0.276372798365	1.25607340258
288	0.233567184685	0.248209969753	0.157960375532	0.148911504972
300	0.30952	0.319740016197	0.165767212427	0.58218971583
312	0.239652503833	0.395260050674	0.19183983403	0.228435251798
324	0.332382908831	0.265878354052	0.170127262813	0.384548617252
336	0.496980661144	0.135371119176	0.2122781205	0.690027084111
348	0.401339526252	0.190877914926	0.150158617644	0.242149036324

shows that path between home agent and correspondent node in the mobile IPv6 network has 3.6 times better throughput than RSVP extension approach. Besides, our proposed approach improves link throughput 6 times toward the HMRSVP approach. There is an increase in throughput in each approach illustrated in Figure 8. The reason is, as we mentioned earlier, link between Atlanta and Washington fails at time 700 seconds and back to the network at 1000 seconds. During this period of time traffics are diverted to created bypass route.

7. Numerical Example.

Table 5 presents statistic data for four intermediate routers presented at the simulation environment.

8. Conclusions.

In this paper, we have proposed a model to calculate maximum bound of end-to-end delay through the intermediate routers. This bound is based on statistical services and allows a fraction of traffic to exceed QoS requirements. Each intermediate router along the guaranteed path determines this bound and makes local resource reservation based on this bound and also sends back this bound to the home agent to calculate cumulative bound. Home agent based on comparison between the cumulative bound and application desired bound make a decision for resource reservation. A direction of this paper is in the case of resource reservation protocol (RSVP) over mobile IPv6 networks. There are numbers of proposed solutions for resource reservation over mobile IPv6 networks, but most of them use advanced resource reservation. Therefore, the way in which resources are allocated and managed is an important issue. Simulation results have shown improvement in the link utilization and throughput in comparison with related works. In conclusion, our scheme sounds to be a viable approach to the RSVP for the following reasons: 1) It is scalable and compatible with RSVP standard and can be implemented at the home agent in the service network where user network is located; 2) It improves the network resource utilization based on effective envelope approach.

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