Performance Analysis of a QoS Management Architecture for an Emergency Scenario

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ABSTRACT

The paper deals with the performance analysis of a recently proposed QoS Management Architecture (QMA) for a communication infrastructure used in an emergency scenario. The performances are evaluated in terms of the most significant QoS parameters by means of a measurement testbed specifically set up in laboratory to emulate a realistic emergency scenario where different operators have to cooperate during the rescue procedure. The QoS parameters are assessed both in absence and presence of the QMA, considering several traffic types. The comparison of the achieved results shows the effectiveness of the considered QMA.

Categories and Subject Descriptors

B.8.2 [Performance and Reliability]: Performance Analysis and Design Aids.

General Terms


Keywords

Performance analysis, QoS management architecture, wireless technologies, emergency management.

1. INTRODUCTION

The experience in emergency management gained by public safety agencies in the world suggests the need of an efficient communication infrastructure able to provide a multiplicity of services with strictly rigorous requirements that allow the emergency operators to cooperate effectively. In this context, heterogeneous terrestrial and satellite wireless access technologies have to interoperate seamlessly to guarantee that each emergency operator can perceive a given satisfactory Quality of Service (QoS). Intense research activity has been promoted on this topic in recent years and several solutions have been suggested. In [1], [2] globally applicable technical specifications for digital mobile broadband technology have been defined by MESA Project, an international partnership between ETSI and TIA. In [3] it is presented a system architecture for the interoperability and integration among Private Mobile Radio (PMR) systems (TETRA), public communication networks (GSM/GPRS/UMTS), and broadband wireless technology (WiFi and WiMax). Such an architecture resorts to appropriate mapping strategies among service classes supported by the different wireless systems. In [4] it is presented an efficient emergency management system that integrates the Mobile Grid paradigm in the communication infrastructure, used to transport and sharing of information among operators, in order to manage in an integrated way QoS provisioning. In [5] it has been proposed an interesting mobile ad-hoc satellite wireless mesh networking approach designed for an emergency scenario, in which, one of the most important requirement, namely, the full mobility, of rescue teams at the disaster site is assured by combining ad-hoc mobility together with IPv6 mobility mechanisms. Finally, in [6] we proposed a QoS provisioning approach in heterogeneous relief network accomplished by resorting to both a specific DiffServ-based procedure and appropriate mapping strategies among DiffServ and the service classes supported by each wireless access technology. Such an approach allows one to benefit from the specific QoS management capabilities of each technology and to guarantee, at the same time, unlike [3], the scalability property against the entry of any new access technology, since the new entry can be managed just adding a new specific QoS management software module without requiring the upgrading of the ones already present in the system.

To substantiate the effectiveness of the QMA of [6] in this paper a performance analysis is carried out by means of a measurement testbed specifically set up in laboratory to emulate a particular emergency scenario where terrestrial, on board of an aerial vehicle, and both local and remote headquarters operators have to collaborate. The performances, measured in terms of end-to-end packet transit delay for voice-packet, packet loss number and percentage and number of TCP retransmissions for remote monitoring and control data, throughput and packet loss number and percentage for video streaming, and throughput for FTP bulk data are evaluated and compared with those achieved in absence of QMA. The paper is organized as follows. In Section II, after a description of the emergency scenario and the envisaged services, it is briefly described the QMA proposed in [6], while Section III is focused on the measurement testbed. In Section IV, performance results in terms of specific QoS parameters are reported. Finally in Section V, conclusions are drawn.

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2. THE QOS MANAGEMENT ARCHITECTURE

In our vision, the communication infrastructure for emergency management has to support the response and recovery phases after natural or man-made disasters have occurred. In these cases, private and/or public communication infrastructures at the crisis site can be compromised or completely out of order, or no-existent and, often, especially during the first beginning phases the anarchy can reign over every rescue action due to the panic of the people. In such a scenario emergency, operators move towards the crisis site reaching the most critical areas of the disaster. It has been widely recognized that it represents a very useful support to get real-time information about the
crisis site by means not only the satellite network but also by a properly equipped aerial vehicle with camera and sensors. It flies over the area affected by disaster and transmits real-time video, images and data to a Mobile Ground Station (MGS), a light vehicle located near the struck area. This station provides support both to local rescuers and remote public safety agencies, thanks to several types of wireless connections. It’s worthwhile to underline that satellite connection is only used if pre-existent wide area terrestrial networks are out of order or no-existent. In particular, in this scenario a ViaSat’s SurfBeam DOCSIS [8] two-way broadband satellite system, operating in KA band, which integrates a Performance Enhancing Proxy (PEP), could be used. Fig. 1 depicts a common emergency scenario and the related relief system architecture.

Figure 1. Emergency scenario and Relief System Architecture

In this emergency scenario, typically used services are VoIP, real time streaming video, remote monitoring by means of Wireless Sensor Networks, remote control, bulk and small data transfer via FTP, and they require very different QoS treatments. To accomplish them, the QoS scheme shown in Fig. 2 has been proposed in [6].

Table 1. Mapping Between Emergency Services and DSCPs

<table>
<thead>
<tr>
<th>Emergency Service</th>
<th>DSCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversational voice</td>
<td>EF</td>
</tr>
<tr>
<td>Remote monitoring and control</td>
<td>AF11</td>
</tr>
<tr>
<td>Real-time Video</td>
<td>AF12</td>
</tr>
<tr>
<td>Instant messaging</td>
<td>AF21</td>
</tr>
<tr>
<td>Small data transfer/retrieval</td>
<td>AF22</td>
</tr>
<tr>
<td>Bulk data transfer/retrieval</td>
<td>AF23</td>
</tr>
</tbody>
</table>

Table 2. Mappings table

<table>
<thead>
<tr>
<th>DiffServ</th>
<th>3GPP HSDPA</th>
<th>WiFi (802.11e)</th>
<th>WiMax (802.16e)</th>
<th>TETRA</th>
<th>Satellite Doxes L.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF (Expedited Forwarding)</td>
<td>Conversational class (real-time conversational)</td>
<td>Highest priority Traffic Class (TC7)</td>
<td>UGS (Unsolicited Grant Services)</td>
<td>Tele-services and circuit switched data transfer services</td>
<td>UGS (Unsolicited Grant Services)</td>
</tr>
<tr>
<td>AF1 (Assured Forwarding AF11, AF12)</td>
<td>Streaming class (streaming real-time)</td>
<td>Middle-high priority Traffic Classes (TC6, TC5)</td>
<td>rtPS (Real-time Polling Service)</td>
<td>Connects on oriented, switched real time services</td>
<td>rtPS (Real-time Polling Service)</td>
</tr>
<tr>
<td>AF2 (Assured Forwarding AF21, AF22, AF23)</td>
<td>Interactive class (Interactive best effort)</td>
<td>Middle-low priority Traffic Classes (TC4, TC3, TC2)</td>
<td>nrtPS (Non-real-time Polling Service)</td>
<td>Connects on oriented, packet switched real time data services</td>
<td>nrtPS (Non-real-time Polling Service)</td>
</tr>
<tr>
<td>BE (Best Effort) class</td>
<td>Background (background best effort)</td>
<td>Lowest priority Traffic class (TC1)</td>
<td>BE (Best Effort)</td>
<td>Connects on packet switched data services</td>
<td>BE (Best Effort)</td>
</tr>
</tbody>
</table>

This scheme is substantially the combination among well-known coarse-grained DiffServ approach and adequate mapping strategies of the service classes of each wireless technology with DiffServ classes.
3. MEASUREMENT TESTBED
The proposed QoS management solution has been investigated by means of a testing campaign run on a laboratory measurement testbed. Fig. 3 depicts the measurement testbed architecture with QMA.

Figure 3. Measurement Testbed Architecture with QMA

More specifically, air-ground, wireless ad-hoc and satellite segments have been considered to emulate a particular emergency scenario where territorial, on board of an aerial vehicle, and both local and remote headquarters operators have to effectively collaborate.

In particular, air-ground segment has been emulated by Wideband Radio Channel Emulator made by Elektrobit, named PropsimC2. It connects AAP to GAP in RF mode, modeling real world propagation phenomena such as multi-path and fast fading, sliding delays, path loss, doppler shift, and shadowing in laboratory conditions. Wireless ad-hoc segment has been emulated by the laptop-G connected to the local DGGN-L by means of 802.11g interface configured in ad-hoc mode. Local and remote headquarters have been respectively emulated by the desktop-L and the desktop-R personal computers connected to respective DGGNs. Note that the remote DGGN-R has been connected to the local DGGN-L by means a satellite system called SurfBeam, provided by ViaSat Inc. whose related European service, named TOOWAY, is operated by Eutelsat. In particular, the local DGGN-L is located in the National Laboratory of CNIT in Naples, and the remote DGGN-R is located at the DIBET Laboratory of University of Naples Federico II. Finally, DAN and DGGNs have been realized by Commercial Off-The-Shelf (COTS) mini PC with Linux OS whose kernel has been recompiled to support traffic condition and advanced routing modules [9], [10]. Moreover, software modules have been properly developed in C++ language using MAP Standard Template Library (STL) containers to implement mapping tables integrated with DiffServ scheme in order to accomplish a full QMA.

A traffic generator and measurement tool software, referred to as IP Traffic Test & Measure developed by ZTI [11], has been installed on both laptops and desktop PCs of the measurement testbed in order to generate traffic emulating some emergency services and to measure fundamental QoS parameters. Finally, Windows Media Encoder has been installed on the laptop-A to send test video by means the emulated link connecting the aerial vehicle with the Mobile Ground Station.

4. PERFORMANCE RESULT
The testing sessions have been carried out by sending audio and video streaming, remote monitoring and bulk data on different ports in order to verify the different treatment operated on different traffic flows. In particular, real audio and video traffics have been captured by means of ZTI Sniffer Module, and replayed by ZTI IP Generator Module that also performs remote monitoring and FTP bulk data traffics with user-defined patterns. In this way, the generated traffic flows are replicable. Different statistic parameters are displayed by the ZTI Traffic Observer Module installed on receiver. Two different measurement scenarios have been emulated: the first one considers the transmission from the laptop-A to the desktop-R, employing 802.11g, 802.3 and ViaSat’s SurfBeam DOCSIS communication technologies; the second one from the laptop-A to the laptop-G, employing 802.11g, 802.3 and 802.11g in ad-hoc mode. To emulate air-ground link a multipath channel model with seven equally spaced paths is considered: the maximum delay is equal to 5 ms and the power associated with the Line of Sight (LOS) path is about 90% of the received signal power. The considered speed, which affects the variability of random signal reflections, is equal to 50 km/h. In both scenarios the measurements have been carried out with and without proposed QoS management solution, considering the following traffic flows: RTP on UDP audio stream with constant bit-rate equal to 25 kbps, RTSP on TCP video stream with average bit-rate equal to 400 kbps, FTP bulk data supposed with a continuous amount of transmitting data and TELNET data with a random pattern. QMA, through the HTB qdisc, implemented in our Linux boxes (DAN and DGGNs), creates two classes and the maximum rate, which each class can consume, has been set to assure that the AF1 traffic aggregate occupies the max bandwidth of 450 kbps and the AF2 traffic aggregate occupies the max bandwidth of 500 kbps, being the satellite operational bit rate equal to 1 Mbps. For the EF traffic, instead, the highest priority has been set in order to preserve the conversational voice flow in each condition. The considered QoS parameters are throughput, packet loss number and percentage, number of TCP retransmissions and end-to-end packet transit delay. We assume that the quality of audio service is good if end-to-end packet transit delay is below 10 ms, while the quality of video service is acceptable if average throughput is about 400 kbps and packet loss percentage is below 5%. The results obtained by ZTI IP Traffic Test & Measure tool have been exported in CSV format to simultaneously visualize the trend of parameters of considered traffic flows. The effectiveness of the proposed QoS management solution is shown by the Fig. 4, Fig. 5 and Table 3. Table 4 in terms of throughput, packet loss number and percentage and the number of TCP retransmissions with reference of the first considered scenario, while by the Fig. 6 and Fig. 7 in terms of end packet transit delay with reference of the second considered scenario.

More specifically, Fig. 4 shows that, without QMA, video streaming average throughput is about 300 kbps and therefore less than the required 400 kbps video bit-rate, due to bandwidth sharing with FTP service. It is possible to observe the classic TCP sawtooth pattern due to Additive Increase Multiple Decrease (AIMD) mechanism of TCP that combines linear growth of the congestion window with an exponential reduction when a congestion event occurs. Note also that no bandwidth is guaranteed for video streaming service in case of deterioration of the channel conditions; in fact video streaming throughput decreases similarly to FTP one. Audio streaming throughput, instead, does not decrease because it is transmitted over UDP. In Fig. 5 is depicted the throughput trend for different flows in presence of our QMA. Note that, now, video streaming average throughput is about 400 kbps, as required, whereas the FTP throughput decreases to about 350 kbps. In presence of a degradation of the channel conditions, FTP throughput value drops to 0 (see Fig. 5 at 30s) and video streaming throughput undergoes a contained decrease. Also in this case, audio streaming throughput does not decrease.

PERFORMANCE RESULT

DATA TABLES

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>Throughput (kbps)</th>
<th>Packet Loss (%)</th>
<th>TCP Retransmissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTP (UDP)</td>
<td>400</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RTSP (TCP)</td>
<td>400</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

MEASUREMENT RESULTS

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Throughput (kbps)</th>
<th>Packet Loss (%)</th>
<th>TCP Retransmissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>300</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Remote</td>
<td>300</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

FIGURE 3

- Measurements Testbed Architecture with QMA
- A traffic generator and measurement tool software, referred to as IP Traffic Test & Measure developed by ZTI [11], has been installed on both laptops and desktop PCs of the measurement testbed in order to generate traffic emulating some emergency services and to measure fundamental QoS parameters. Finally, Windows Media Encoder has been installed on the laptop-A to send test video by means the emulated link connecting the aerial vehicle with the Mobile Ground Station.
Table 3. Statistics without QMA

<table>
<thead>
<tr>
<th>Data</th>
<th>N.packets</th>
<th>N.Lost</th>
<th>% Lost</th>
<th>Retransmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUDIO</td>
<td>3844</td>
<td>231</td>
<td>6,01</td>
<td>N/A</td>
</tr>
<tr>
<td>TELNET</td>
<td>240</td>
<td>1</td>
<td>0,41</td>
<td>1</td>
</tr>
<tr>
<td>VIDEO</td>
<td>5111</td>
<td>26</td>
<td>0,51</td>
<td>10</td>
</tr>
<tr>
<td>FTP</td>
<td>5187</td>
<td>35</td>
<td>0,67</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 3 shows that the packet loss percentage and the number of TCP retransmissions in absence of treatment are almost similar for all TCP flows, as expected. Note that audio streaming percentage packet loss is higher than TCP one because UDP does not provide any type of flow and congestion control. In presence of QMA, TELNET data flow does not lose any packet and it doesn’t undergo any retransmission, and video streaming gets a significant benefit, as shown in Table 4. In these conditions the packet loss percentage and the number of TCP retransmissions of FTP data flow is very high, as expected. With reference to the second measurement scenario, Fig. 6 and Fig. 7 compare audio streaming end-to-end packet transit delay with and without QMA. In particular, with QMA, end-to-end packet transit delay is always below 10 ms. Without QMA, end-to-end packet transit delay appears to be acceptable, thanks to UDP transmission mode, but when the channel conditions degrade the end-to-end packet transit delay increases up to 120 ms, resulting in unacceptable quality.
5. CONCLUSIONS

The paper deals with the performance analysis of a QoS Management Architecture (QMA) recently proposed by the authors for a communication infrastructure used in an emergency scenario. At this end a measurement testbed has been set up in laboratory, emulating a realistic emergency scenario where terrestrial, on board of an aerial vehicle, and both local and remote headquarters operators have to collaborate using a multiplicity of services. The performances are evaluated in terms of the most significant QoS parameters with and without QMA. The performance comparison shows the effectiveness of the proposed QMA which is able to provide seamless QoS support for audio, video, remote control and other emergency services. The integration of WSNs (Wireless Sensor Networks) in QMA is currently under study in order to provide forecast capability to the Emergency Management Network.

REFERENCES