IoT Based Security Management Framework for Heterogeneous Network Environment

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Abstract
In an effort to curb the potential losses associated with the event of security bridge, admitting the uneven bandwidth support that characterizes most developing smart cities, we propose a neural inspired Multimodal Security Management System (MSMS) that is bandwidth-tolerant. The proposed system leverages on a Next-Generation Network (NGN) architecture in catering for the challenges associated with the provisioning of ubiquitous broadband access for IoT support in a heterogeneous morphological network environment. In order to evaluate the MSMS, we simulated the proposed cloud-based system on a Next Generation Network (NGN) architecture which utilizes Internet Protocol/Multi-Protocol Label Switching (IP/MPLS) as transport technique in a Long Term Evolution (LTE) backbone infrastructure. We then compare its performance over a competitive alternative transport technique: "Internet Protocol Asynchronous Transfer Mode (IP/ATM)". Thus, we further evaluated the MEMS on the latter architecture. While, our proposed system is able to capture both textual, aural, and visual information of individuals in security vulnerable environments via installed smart microphones and cameras, it is also able to integrate this information's in predicting security threats. When compared with the popular Security Management System (SMS) "ShotSpotter", results show that our proposed system outperforms the ShotSpotter system by 0.87 and 0.45 in terms of efficiency and response time respectively. Finally, simulation of our proposed system on an IP/MPLS transport schemes shows that the former outperforms the latter with respect to overall network bandwidth utilization and average traffic loss in the ratio of 0.098 and 0.087 respectively.

Keywords
ATM, MSMS, MPLS, IoTs, LTE

1. Introduction
There is currently an alarming upsurge of people from all works of life to urban cities mostly in search for better living condition. According to the United Nations, by 2050, over sixty-eight percent of the world's population will be urban dwellers [1, 2]. Currently, concerted efforts are geared towards ensuring that many of these urban centers are furnished with technologies that support for improved day to day engagement of persons via provisioning of digitized services such as: online bill payments and banking, apps for services like transport management, health care provisioning and online communities for welfare of individuals. Many of these cities leverage on Internet of Things (IoT) to connect operational technology, such as smart meters, sensors while utilizing artificial intelligence (AI) to make sense of all the data for improved service delivery to residence. However, little effort has been geared toward the physical safety of persons and things in these environments amidst the growing rate of crime and suicide bombings in many of these cities [3, 4].

Disaster outburst are characterized by a total or partial disruption of the normal functionality of any society within a short-time. They are usually marked by extensive human, economic, material and environmental losses, with a resultant decapitation of the affected community and hampering of its ability to cope with its own resources [5, 6].

Studies have revealed that disaster outbreaks, are an upshot of inadequate risk management plan. Thus, the great call on stakeholders to make concerted efforts in ensuring that the damages (human and resources) incurred in the event of these unforeseen circumstances be brought to the barest minimal and in cases where such outbreak could be averted, mechanisms to ensure prompt and adequate prevention of their occurrence be taken [4].In this regards, several first world countries have leveraged on the use of cloud based technologies such as "ShotSpotter" in managing crime outbreak. Many growing cities on the other hand, currently lag behind in this drive as they still have the challenge of poor technological infrastructural deployment such as broadband penetration to contend with [7, 8].

The advent of the internet has tremendously influenced the way people live and interact, with most of the current interactions occurring at virtual level. Similarly, the recent drive towards providing ubiquitous connectivity for things, inspired by the internet of things (IoT) revolution, has also set in a new dimension of interaction. Interaction has transcended from human to human in the physical and virtual space to interaction with things. The enormous impact of this new wave is currently visible in both public and domestic domains, with application in e-health systems, domestics assisting, improved learning systems, logistics, automation, intelligent transportation of people and goods, industrial manufacturing and business/process management. Many developing countries have in recent time adopted the use of IoT based technologies in forecasting disaster/crime occurrence and in its management. However, while many researchers are of the opinion that this technology may not be able to stop crimes from occurring, others suggest that these technologies could be leveraged on in developing solutions for security and disaster management in the form of predictions and early warning [4, 9].

In many developing nations, there is a growing demand for mobile broadband internet access. While the present reality in these regions reveal a bias in the distribution of broadband access along lines of morphological and demography of the cities, and this possess a great challenge to IoT based solutions being developed for security and crime management in these cities. However, NGN comes as a remedy to the aforementioned challenge as it reshapes the current model of communication systems and ingress to the Internet by transforming the existing structure of vertically independent, but integrated networks into a horizontal form of networks established on IP [10].

In this work, we propose a novel, architecture for security management systems for smart cities. The proposed cloud-based system, utilizes textual, aural, visual information from installed sophisticated microphones and cameras in strategic locations in the cities such as train station, parks and school and is able to integrate the captured information in making prediction of crime susceptible environment. The proposed system, also thrives on a bandwidth tolerant architecture (NGN architecture) for both front end and back end connectivity.

To achieve the precise intent of this work, the rest of this work is ordered as thus: Section 2 provides an overview of the current security management system for cities and then an overview of the LTE backbone architecture for NGN. Section 3 give an analytical insight into the proposed neural inspired MSMS framework and adopted back end resource optimization algorithm for the system. Furthermore, in section 4 we carry out the simulation of the system on the adopted network architecture and transport scheme, and also investigate their performance by subjecting the traffic from the system to the developed traffic model. The results obtained from the simulation are analyzed and discussed. Finally, Section 5 concludes and makes recommendations for future work.

2. IoT based Security Management Systems and LTE Backbone Infrastructure

The Internet of Things (IoTs) has paved way for the development of smart applications which have found utilization in vast domain as shown in Fig. 1. While IoT has aided the development of smarter security systems for homes and industries, it has rarely been utilized in the developing policing systems for persons in public sphere. The "ShotSpotter", which is currently the technology mostly used in many cities, is built on existing surveillance tools, of which many have been adjudged outdated as they are characterized by grainy-video cameras that do not capture sounds at crime scene but only produces footage that can only be reviewed by the city policing department, after crimes have been committed. Thus, rendering such a system not smart in any sense and unfit as a security infrastructure for smart cities [11, 12].

Recently, Huawei, one of the world's leading information and communications technology (ICT) solution provider, developed a robust cloud-based smart city solutions, which leverages on a web of interconnected devices, software and storage systems in aiding public and private services to work together more efficiently. Also, Huawei is currently utilizing this IoT-based solution in affording state of the arts tools for governments in in improving public services such as crime-fighting, and to keep an eye on what is going generally in the public sphere as in Fig.1. This safe city solution utilizes enterprise LTE technology to link interconnected devices with secure wireless broadband connectivity, together with sundry fixed line, fiber and microwave technologies. While the government of some developing economy in Africa, such as Kenya which is a tourist hub, is embarrassing this solution in a bid to ensure a safe economic sphere for viable commercial growth; many developing countries on the other hand still have the challenge of efficient internet connectivity to contend within most urban cities. As a contribution, we seek to explore the use of a new integration architecture to ameliorate the challenge posed by uneven bandwidth distribution across most urban cities [11-14].

Figure 1: A Smart city with a smart policing network

Over the years, there have been an upsurge in the clamor for government to ascribe high priority to public security. Security architecture for Policing service needs to be furnished with sophisticated surveillance systems with high-speed public and private broadband network operating on satellite-based GPS and software based GIS; and at the back-end, an intelligent video analysis platform to manage video resources and meet a variety of service needs, including real-time surveillance, video browsing, data sharing and evidence collection all geared towards enhanced police collaboration, coordination, decision-making and response times [12]. As a major contribution of this studies we show how improved inference can be made from a fusion of extracted information from back-end real-time video resource of crime scene and how that can improve the current policing architecture in most developing counties.

2.1. Transport Networks for LTE Core

The backbone of every communication network is usually a central node (Core) furnished with high capacity to provide communication paths between applications and different sub-networks. The Core provides any-to-any connectivity and has the ability to handle very high volumes of data at very high speeds from any source to any destination. However, with the coming of the internet, increased demand for bandwidth for most new networks, and the demand for connectivity for all things i.e. Internet of Things (IoT), there has been a great need for improved capacity for the core in terms of efficiency. This is as a result of demand for ubiquitous high-speed connectivity by subscribers. NGN, which is envisioned to transforms the present vertically independent, although interconnected networks to a horizontal structure of networks based on IP, would proffer a central structure through the interconnection of several networks with different transport and control technologies as shown in fig.2. It promises to uniquely, unify multi-service platform [19-21]. It aims at providing ubiquitous next-generation broadband services experience to users not minding their host network. LTE fits in as a backbone network for this future network as it can provide high capacity support for this overlay of networks. It also has the capability to provide broadband capacity with high efficiency, reduced latency improved capacity and seamless mobility management and resource provisioning [9].

Today, IP/MPLS is a widely used technology in Core Networks. Similarly, ATM which is a connection-oriented transport technique is also used at the backbones of some public networks. Its ability to dynamically allocate bandwidth, support a variety of traffic classes with changing flow characteristics and scalability in speed make it also an admirable transport technique to adopt for the future core network [12, 14].

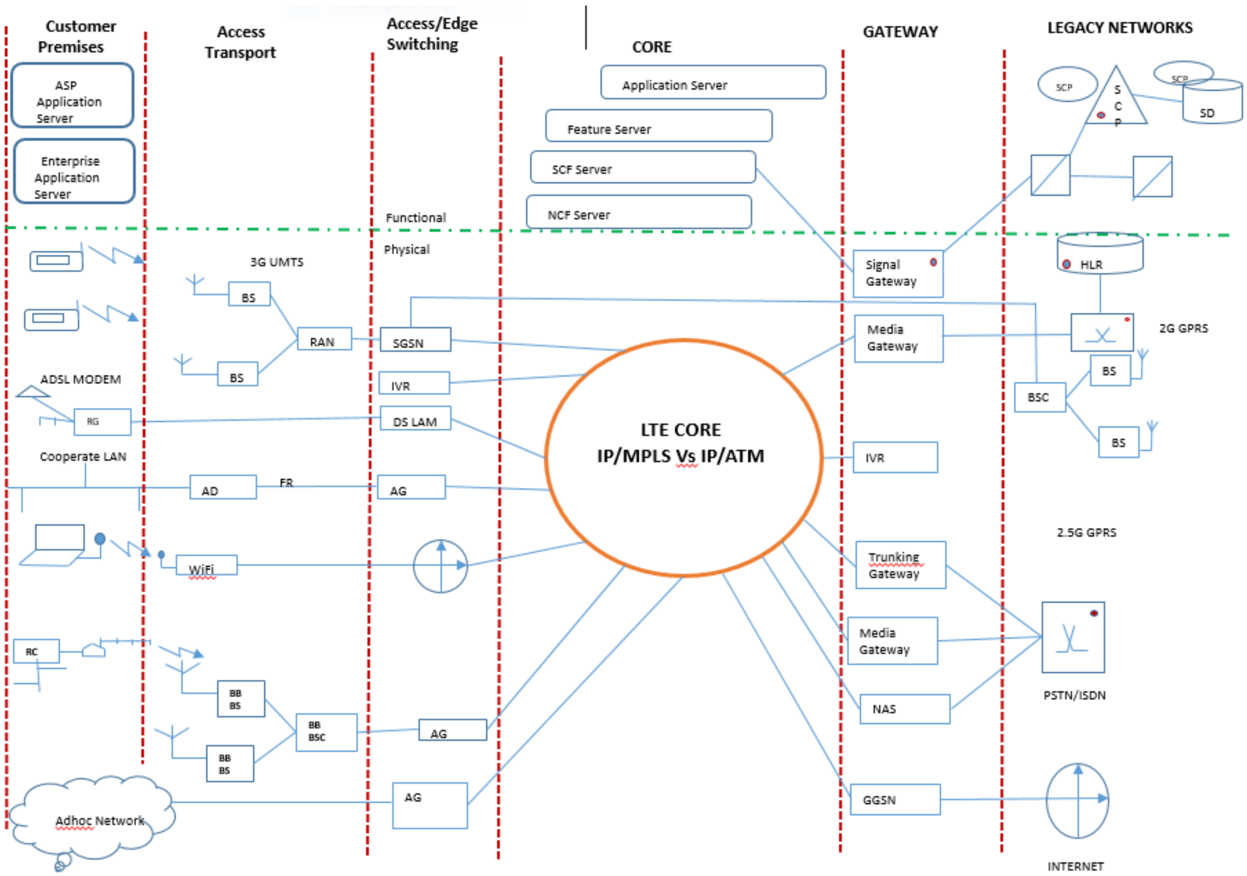

Figure 2: NGN Convergence Architecture

2.2 Cloud Based Architecture for Multimodal Security Management System

Cloud based computing has in the last decade, gained significant interest and development both from the research community and the technological world. This is to great extent attributable to the consistently increasing number of smartphones and mobile devices with internet connecting demand. Thus, resulting in a paradigm shift from standalone computing to cloud computing with a vast majority of the computing done today carried out online. The potentials inherent in this technology ranges from: better operational cost saving for organizations to improved flexibility in capacity, time management and effective use of computing resources. Based on ownership and users, cloud computing categories into four groups: private, public, community and hybrid [15, 16], with each having inherent advantages and disadvantages. The onus of the choice of cloud computing technology to be deployed for a particular technology lies on the technological experts who are most times guided by the sensitivity of the application and the available cost clients are willing to set out for such a project. In this study, we would be adopting a public cloud architecture as shown in Fig.3.

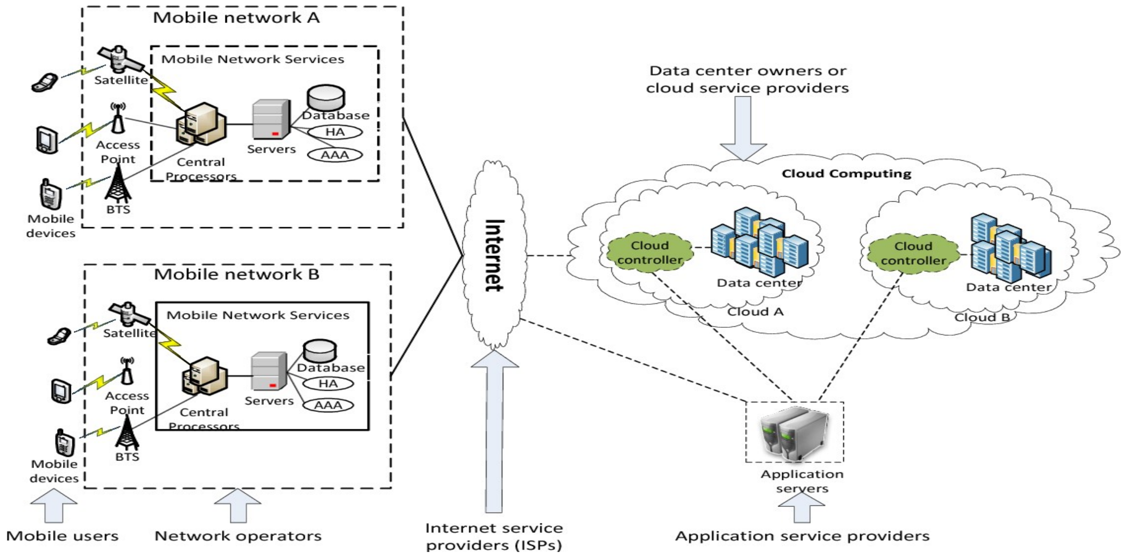

Figure.3: Cloud-Based Architecture for MSMs

3. Empirical Model for MSMS Framework and Backbone Resource Optimization Algorithm

For the proposed study, we adopt a corpus in which the utterances are systematically dependent and have greater scene of crime. This implies that the contextual meaning of utterances in a given video can only be efficiently deduced if the utterances in proceeding video clips are taken into consideration.

Similarly, while IP/MPLS is a widely used technology in Core Networks [3, 17], ATM a connection-oriented transport technique is also used at the backbones of some public networks owing to its ability to dynamically allocate bandwidth, support a variety of traffic classes with changing flow characteristics and scalability in speed make it also an admirable transport technique to adopt for the future core network. Thus, we also present an analytical overview of these two schemes

3.1. Feature Extraction and Fusion Model for MSMs

We adopt the analytical model proposed by [15] and thus, represent the unimodal features extracted from videos as:

$$f_T = \in R^{N*d_T} \quad \text{Textual features} \tag{1}$$

$$f_A = \in R^{N*d_T} \quad \text{Acoustic features} \tag{2}$$

$$f_V = \in R^{N*d_T} \quad \text{Visual features} \tag{3}$$

Where N is the maximum number of utterances in a given video. It is important to note that utterances in the different video have varying length as such dummy utterances represented by null vectors were utilized in padding these utterances. Similarly, each unimodal utterance feature f_m of a video is feed to a GRU_m with output size defined as:

$$z_m = \delta\left(f_{mt} U^{mz} + S_{m(t-1)} W^{mz}\right) \tag{4}$$

$$r_m = \delta\left(f_{mt} U^{mz} + S_{m(t-1)} W^{mr}\right) \tag{5}$$

$$h_{mt} = \tanh\left(f_{mt} U^{mh} + S_{m(t-1)} * r_m * W^{mh}\right) \tag{6}$$

$$F_{mt} = \tanh\left(h_{mt} U^{mx} + U^{mx}\right) \quad (7)$$

$$S_{mt} = \left((1 - z_m) * F_{mt} * z_m * S_{m(t-1)}\right) \quad (8)$$

Where $m\langle T, A, V\rangle$, $U^{mz} \in R^{d_m * D_m}$, $W^{mz} \in R^{D_m * D_m}$, $U^{mr} \in R^{d_m * D_m}$, $W^{mr} \in R^{D_m * D_m}$, $U^{mh} \in R^{d_m * D_m}$, $W^{mh} \in R^{D_m * D_m}$, $U^{mx} \in R^{d_m * D_m}$, $U^{mx} \in R^{D_m}$, $z_m \in R^{D_m}$, $r_m \in R^{D_m}$, $h_{mt} \in R^{D_m}$, $F_{mt} \in R^{D_m}$ and $S_{mt} \in R^{D_m}$

This yield hidden outputs F_{mt} as context aware unimodal features for each modality. Hence we have:

$$F_T = GRU_T\left(f_T\right) \quad (9)$$

$$F_A = GRU_A\left(f_A\right) \quad (10)$$

$$F_V = GRU_V\left(f_V\right) \quad (11)$$

Finally, these modalities were fused by concatenating each modality thus resulting in:

$$F_A = \left[F_T ; F_A ; F_V\right] \quad (12)$$

This is then fed into a contextual GRU i.e. GRU_{TAV}

3.2. IP/MPLS and IP/ATM Transport Models for Core Network

We adopt the analytical model proposed in [14] for this study. Here packet loss and re-transmission due to link overload are managed using load balancing. Where the weight of a given path is normalized using (13):

$$W_k = \frac{P_k}{\sum_{i=1}^{n} P_i} \quad (13)$$

where P_k is given as:

$$P_k = \left(\frac{AHP\_Cost(Path_k)}{\sum_{i=1}^{n} AHP\_Cost(Path_i)}\right) \quad (14)$$

Similarly, the cell loss and re-transmission for the IP/ATM core is modeled as:

$$Cell\_loss\_rate = \left(\frac{Number\_of\_cells\_rejected}{Number\_of\_cells\_through\_queue + Number\_of\_cells\_rejected}\right) \quad (15)$$

4. Simulation and Results Analysis

In a bid to realize the objectives of this studies, we utilized two platforms for modeling and simulating the intelligent video analysis module and the network resource allocation module respectively. These modules are thus explained in details in the following sections.

4.1. Intelligent Video Analysis

Overtime, several literatures have advocated for multimodal approach to affect recognition and prediction. This entails the fusion of information from different modalities for more robust affect prediction. At present, there are currently two main types of fusion in this domain: feature-level and decision-level fusion respectively. While in feature-level fusion, the extracted features from the various modalities are fused to form a general feature that is finally analyzed for proposed task. The decision-level fusion on the other hand, classifies features from each modality independently before the results are fused as a decision vector. For this studies, we adopt a hybrid architecture as shown in fig. 4.

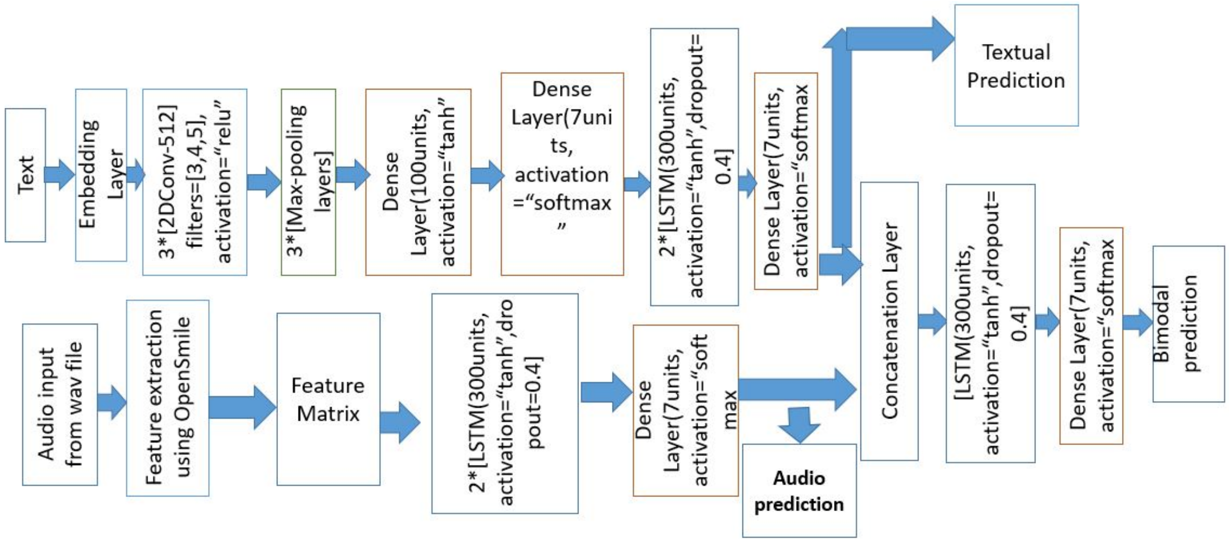

Fig.4: Deep Neural Architecture for Multimodal Affect Estimation

From the adopted corpus for the study, utterances in the text were represented as an array of pre-trained 300 dimensional Glove vectors. Also, acoustic information were extracted using pyAudioAnalysis toolkit. The choice of this toolkit was inspired by it capacity to capture both the acoustic and prosodic features in a speech signal. Using this kit, we adopted the Mid-term feature extraction. The Mid-term feature extraction has the capacity to extract the mean and standard deviation over each window of the short-term feature sequence of the pyAudioAnalysis toolkit. A total of 64 features were extracted per frame using this kit. Similarly, visual information where extracted by foremost splitting each video clip into frames and then we adopted the use of Faster R-CNN in identifying interlocutors from each frame. This second step was born out of the need to reduce the noise contributed by the background since the corpus is practical made of real-life interaction scenarios. From the identified interlocutors in each frame, visual features such as facial landmarks, head orientation, facial action units and gaze tracking were extracted using VGG16. Finally, the mean value of these features obtained from the individual frames that constitute a video clip and then subsequently fed into the model in fig.4. Result from the resulting affect estimation are show in fig.5-8 for textual, aural, visual and a combination of all three modalities. The result shows a great improvement in affect prediction when modalities are combined. This approach can thus be adopted by policing agencies in monitoring and analyzing clips from public sphere in a bid to predict events that could lead to a breakdown of law and order.

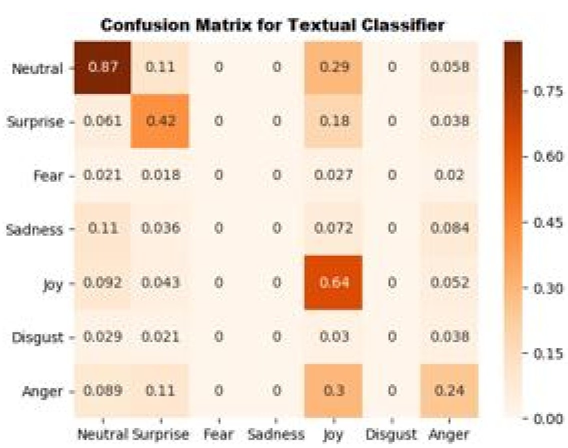

Fig. 5. Textual Affect Estimation

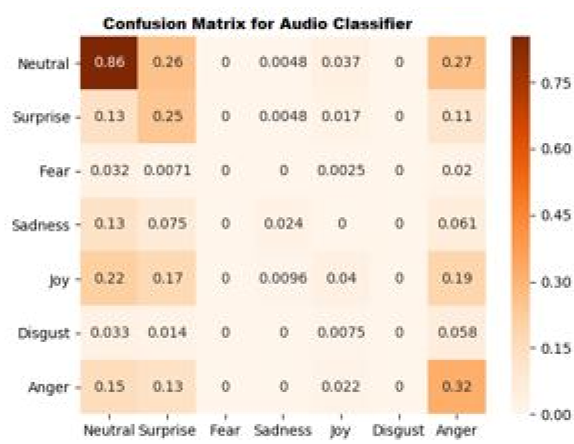

Fig. 6. Acoustic Affect Estimation

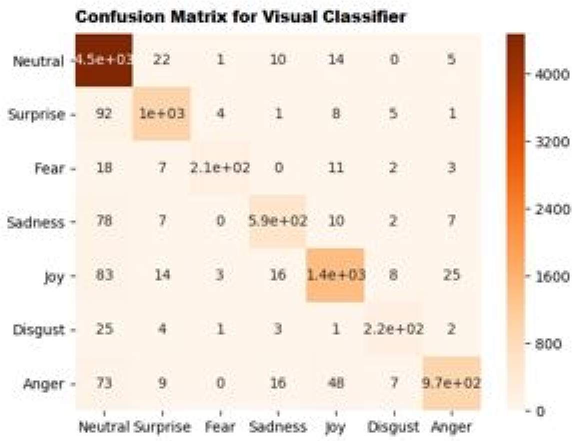

Fig. 7. Visual Affect Estimation

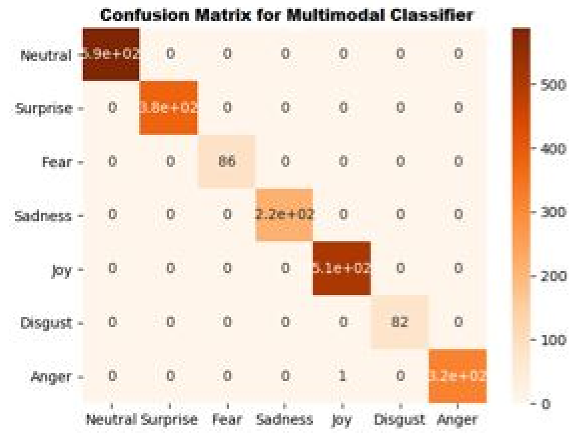

Fig. 8. Multimodal Affect Estimation

4.1. Integrated Network Analysis for MSMs

In this section, we evaluate the performance of the adopted NGN integrated architecture for the support of the proposed MSMs. In this regard, we modeled an unvarying arrival and continuous service process flow for the backbone network. Traffics were modeled as Markov Modulated Poisson Process (MMPP) in MATLAB/Simulink environment with set parameters for supported class of traffic generated by typical Users in Urban center and in particular the proposed MSMs. This is to account for bustiness of the envisioned future multimedia services to be supported in the networks.

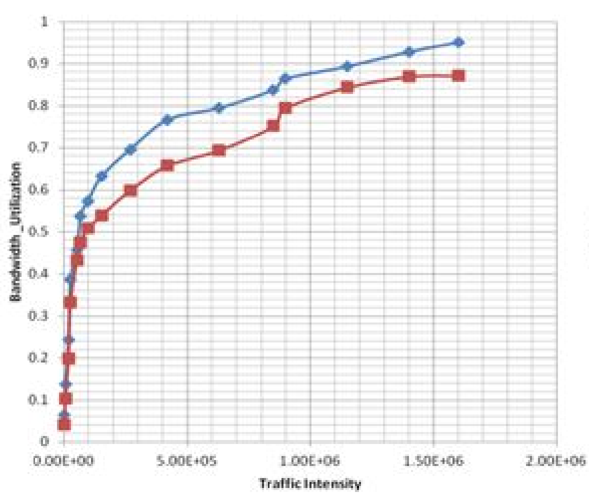

Fig. 9. Backbone Bandwidth Utilization

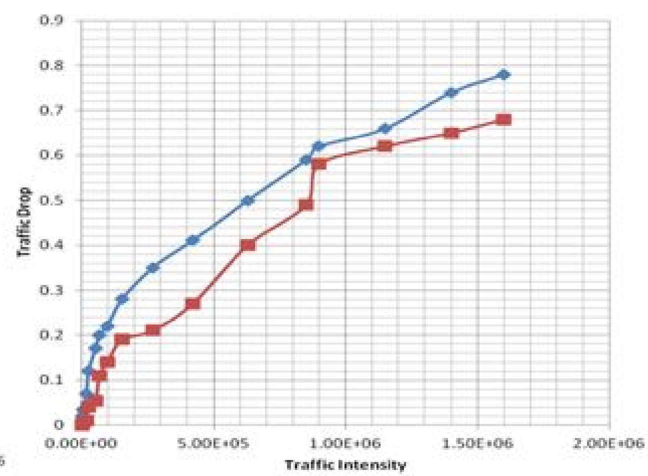

Fig. 10. Overall Network Traffic Drop

We further evaluated the performance of the core network in terms of two fundamental metrics: overall utilization of the back-end resource (bandwidth) and traffic drop across the entire network. The results are shown in fig.9-10. The evaluation was done on two backbone transport techniques (IP/MPLS and IP/ATM) as discussed in section 3.2. Results from the analysis show that IP/ATM offers a strong competitive edge over the former when utilized as core transport technique.

5. Conclusion

We have been able to establish in this study that Next Generation Network (NGN) which aims at completely reshaping the current model of communication systems and ingress to the Internet also has the capacity to argument for the bandwidth deficiencies that characterize earlier generations of mobile networks. It is intended to transform the existing structure of vertically independent, but integrated networks into a horizontal form of networks established on IP. This central platform architecture brings existing networks with varying transport and control technologies into a distinct, coalesce and multi-service structure formed on IP. Similarly, we show that though IP/MPLS is currently the currently the adopted transport technique in this architecture, IP/ATM offers a competitive alternative transport technique in terms of backbone bandwidth utilization and overall network traffic drop. Also, we show that real time harvesting of surveillance information through intelligent video analysis can enhance policing in public sphere. We establish that the fusion of extracted information from back-end real-time video resource of crime scene can help improve the current policing architecture in most developing counties. Finally, in other to encourage further research in this domain, would be looking at building a more robust multimedia crime base corpus that would be made publicly available to encourage studies and technological innovation that are AI based for a better and safer public sphere in most developing third

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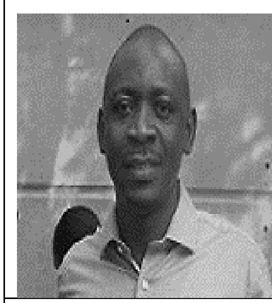	**Eustace M. Dogo** is working towards his PhD. degree at the Department of Electrical and Electronic Engineering Science/Institute for Intelligent Systems, University of Johannesburg, South Africa. He holds B.Sc. and M.Eng degrees in Electrical Engineering from Peter the Great St. Petersburg Polytechnic University, Russia. He lectures at the Department of Computer Engineering, Federal University of Technology Minna, Nigeria. He has published several scholarly research articles and book chapters in his areas of interest. He has extensive knowledge in practice, research, training and teaching. His research interest is in theoretical and applied machine learning, data science and emerging technologies.
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