A Networking Scheme for an Internet of Things Integration Platform

Anderson Augusto Simiscuka
School of Electronic Engineering
Dublin City University
anderson.simiscuka2@mail.dcu.ie

Cristina Hava Muntean
School of Computing
National College of Ireland
cristina.muntean@ncirl.ie

Gabriel-Miro Muntean
School of Electronic Engineering
Dublin City University
gabriel.muntean@dcu.ie

***Abstract*— The Internet of Things (IoT) enables several heterogeneous devices, sensors, wearables, appliances and many other objects to inter-communicate and provide support for heterogeneous services. An IoT network needs to enable exchange diverse data types including multimedia and sensor data and be capable of handling a large number of IoT objects offering services at high quality levels. This paper proposes NETSMITS, an innovative IoT solution which improves the performance and quality of IoT services. It uses a layered architecture that consists of IoT objects, which provide diverse services including video applications and CCTV monitoring, smart gateways, which support IoT object network connectivity and a cloud-deployed IoT Integration Platform (ITINP) employed for resource management. NETSMITS introduces an innovative algorithm which uses Quality of Service (QoS) and service relevance metrics in order to efficiently cluster the inter-communicating IoT objects, attach them to the most suitable smart gateway and improve the performance of their services. Simulation-based testing shows how NETSMITS outperforms an existing state of the art solution for delivering video services in terms of QoS metrics such as packet loss.**

Keywords-Internet of Things (IoT), clustering, smart gateways, performance, QoS.

I. INTRODUCTION

The concept of multiple devices, sensors, appliances, or objects in general connected to the Internet, known as the Internet of Things (IoT) is now a reality. In the past 10 years, sensors prices have dropped by 50%, bandwidth-related prices have dropped by more than 97% and processing prices have dropped by more than 98% [1]. These and other recent technological advances in relation to devices, networks, protocols and applications have enabled IoT to offer a wide range of services and is expected to generate an estimated $8 trillion in "value at stake" over the next decade [2].

Thanks to these advances, 25 billion devices are expected to be IoT networked by 2020. There are many challenges in connecting such a large number of devices, i.e. maintain good user perceived Quality of Service (QoS) levels and low energy consumption. Efficient data transmission is another challenge in heterogeneous networks that handle small and large data at the same time i.e. sensor data and high definition videos [3].

It is also expected from IoT solutions that they provide insights and deliver customised experiences for users. Therefore, another challenge is the creation of a smart decision-making network.

This paper proposes the NETworking Scheme for sMart IoT gatewayS (NETSMITS), an innovative IoT solution which supports increased number of inter-communicating IoT objects and maintains higher quality of their offered services. NETSMITS uses an architecture which includes IoT objects, smart gateways and an IoT Integration Platform (ITINP). The IoT objects offer and consume diverse services including video streams, the smart gateways inter-connect the IoT objects and ITINP manages the smart gateways. Simulation-based testing shows how NETSMITS is able to avoid packet loss, allow the highest throughput per device, reduce delay by up to 85% and achieve an increase of 63% in number of devices served.

The rest of this paper is organised as follows. Section II discuses related works and section III introduces the architecture for the proposed NETSMITS solution. Section IV describes NETSMITS communication units and their associated algorithms, and section V presents the simulations-based testing and its results. Finally, the conclusions and future work directions end this paper.

II. RELATED WORKS

The IoT-related research works discussed in this paper are classified in four categories: *IoT architectures*, *IoT protocols and solutions*, *IoT applications* and *clustering and QoS-aware solutions*. These topics are closely related to the solution proposed in this paper and therefore it is important to be discussed in the context of the state-of-the-art.

A. IoT Architectures

Currently, there is no single widely agreed architecture for IoT; instead there are many approaches which employ different IoT architectures.

In [4], Zanella et al. discuss the design, technical solutions, guidelines and deployment of a smart city through an urban IoT, surveying enabling technologies, protocols, and architectures. The authors do not propose any novel protocols, using existing solutions instead.

A resource oriented architecture for the Web of Things is proposed in [5]. The authors introduce a Web of Things architecture based on RESTful principles, suggesting that the HTTP protocol can be used for connecting 'things' to the Internet. However, the authors acknowledge that protocols that minimise network connection and latency remain the best option for applications where raw performance and battery life-time are critical.

Mulligan and Olsson [6] suggest that ICT and mobile network architectures should be integrated in the context of smart cities, merging the strengths of both architectures.

An architecture which includes a novel composition layer simplifying the development work at the level of physical device interaction was introduced in [7]. This new layer supports APIs for third-party service use.

B. IoT Protocols and Solutions

A number of protocols have been proposed for IoT and they have been tested lately. A recently introduced communications protocol, IEEE 802.11ah, features a transmission range up to 1 km and data rates larger than 100 kbps, bringing the classic IEEE 802.11 WLAN user experience to fixed, outdoor, point-to-multi-point applications and machine-to-machine (M2M) use cases. A feasibility study [8] evaluates the link budget of 802.11ah, its achievable data rate and packet size design and compares them to those of other solutions like ZigBee.

An adaptive, compact and optimised registry-based service discovery solution with context awareness for the IoT is presented in [9]. The solution is focused on constrained domains such as 6LoWPAN. It uses CoAP-based RESTful web services to provide a standard interoperable interface which can easily inter-work with HTTP. A clustering scheme (MBPP) for IoT to evaluate performance through computer simulations was proposed in [10].

eDOAS [11] is a scheme that uses mobile devices heterogeneity in order to provide energy-aware adaptive streaming to mobile devices within a WiFi offload scenario.

C. IoT Applications

Solutions at the IoT application layer have also been proposed. A web application framework based on Google Web Toolkit, aimed at enhancing the interaction between humans and things is presented in [12].

A novel concept, Multimedia IoT, is introduced in [13]. The concept is showcased through the implementation of a vehicular application that measures perceived user Quality of Experience (QoE). However, a larger number of applications should be implemented to test both approaches.

D. Clustering and QoS

A sensor cloud testbed with Adaptive QoS (AQoS) is introduced in [14]. The testbed consists of modules, which offer services that implement and study QoS models for Wireless Sensor Network (WSN) applications based on historical data captured from a physical network. The goal of the study is to offer flexibility through reconfiguration of the cloud as a result of a historic data performance analysis.

A general framework for quick decision making in a rapidly changing IoT environment with a Service-Oriented Architecture (SOA) is presented in [15]. Data from clusters is merged to provide a global consensus on the final outcome.

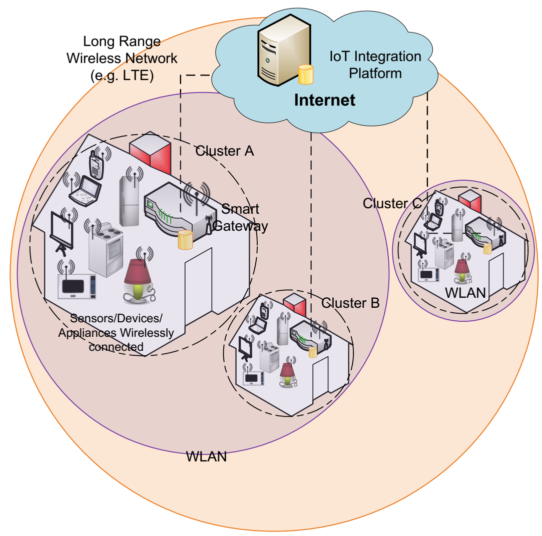


Fig. 1. NETSMITS's High Level IoT-based Architecture

In [16], the author proposes a mechanism for context-aware communication across IoT networks, fulfilling IoT specific communication requirements, while keeping the communication overheads to a minimum. It is also adaptive for different types of IoT networks, available communication interfaces, subscriber-entitlements and changing communication network conditions.

The research work presented in this paper addresses IoT performance challenges identified in the papers presented in this section, especially regarding the number of inter-connected devices.

III. NETSMITS Architecture

The proposed solution, NETSMITS is deployed on an architecture composed of clustered IoT objects (things), smart gateways, and the IoT Integration Platform (ITINP), as illustrated in figure 1. These major components are described next.

A. IoT Objects

IoT objects (i.e. wireless devices, sensor based devices, appliances, etc.) provide one or more services to other objects (e.g. user devices) and are initially connected to the closest smart gateway through a short range wireless protocol (e.g. WiFi) in order to exchange data. However, if an IoT object is more relevant to another object cluster in a distant area (i.e. is associated with high number of requests from that area), it will be attached to a smart gateway serving the new area using long range wireless connectivity (e.g. LTE). This approach decreases the load of the original gateway enabling improved performance for the other object communications. Each object attached to a smart gateway (SG_i) is identified via an ID (O_{ij}) and provides one or more services $S_{ijk,}$ where i identifies the gateway, j indicates the object and k specifies the service.

B. Physical and Logical Clusters

As already mentioned, every IoT object is connected to a smart gateway via short range (e.g. WiFi) or long range (e.g. LTE) wireless communication channel. Initially, objects belong to the closest smart gateway, creating a *physical cluster*, where the distance helps define the cluster. However, some objects' offered services might be more accessed by objects from other clusters and in this scenario the current smart gateway is only being used as a bridge for communications. In order to prevent such a scenario which affects the performance of communications, each object is reassigned regularly to the most relevant smart gateway. If the associated smart gateway is distant, long range wireless solution such as LTE will be used for object-smart gateway communications, creating a *logical cluster*. A logical cluster extends the physical cluster concept by including objects located at various locations with which other objects in this cluster interact more often (i.e. provide or consume services).

C. Smart Gateways

A *smart gateway* is responsible for receiving and sending data from/to objects, managing admission control, aggregating data and storing performance-related information in form of QoS scores. These scores are calculated by an algorithm that considers *throughput*, *delay*, and *loss* and are aggreggated both at the level of objects and smart gateways. Another algorithm calculates objects' relevance scores, considering the percentage of requests coming from different gateways.

Objects send and receive data to/from other objects via the smart gateway they are currently attached to. If an object is trying to reach another object that is located in a different smart gateway, it will be accessed through ITINP, which is accessible from all smart gateways. All smart gateways send their own QoS scores to ITINP and regularly the QoS scores and relevance scores of low performing objects. The smart gateways are aware of objects' location.

D. IoT Integration Platform (ITINP)

ITINP is a cloud-based server platform responsible for creating and managing optimal clusters of objects and assigning them to the best smart gateway. In order to acomplish this task, an algorithm that considers QoS scores and object relevance (both provided by the gateways) is responsible for associating objects to the most suitable smart gateway, in order to establish logical clusters and improve the gateway communication performance. As ITINP is aware of smart gateway locations, if an object cannot reach the most suitable gateway through a short range wireless connection, the object will be requested to use a long range wireless technology to attach itself to the selected gateway.

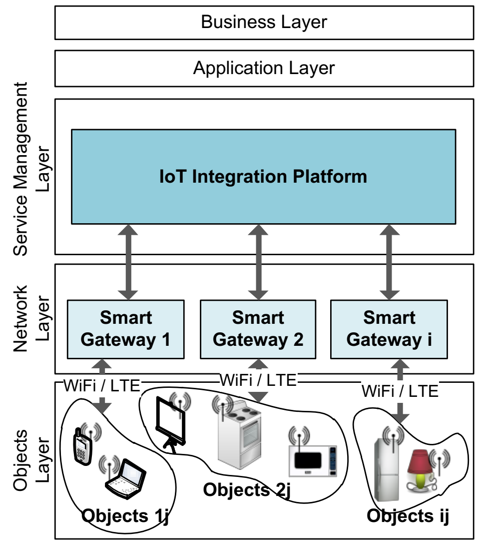


Fig. 2. Layered Architecture

E. Layered Architecture

Each component (i.e. objects, smart gateways and ITINP) belongs to a different layer in a proposed IoT layered architecture. In this paper a five-layer architecture, as discussed in [17] and illustrated in figure 2, is considered. The *Objects layer* comprises the devices, sensors, etc. and communicates with the *Network layer* (sometimes referred to as abstraction layer), where the smart gateways are located. The smart gateways are responsible for clustering local devices, gathering and sending data to improve performance and provide statistics. Smart gateways' data is sent to ITINP, which is located at the *Service Management layer*. This layer is a bridge to the *Applications layer*, where software applications can interact with users or with other machines. Finally, the decision-making is done at the *Business Layer* via Big Data solutions. The Service Management layer is also responsible for controlling the network intelligently, integrating different types of data i.e. multimedia data, sensor data. ITINP performs this tasks in order to maintain high network performance levels.

IV. NETSMITS Algorithms

The proposed solution, NETSMITS involves a clustering scheme for IoT objects based on their services. An algorithm deployed in the cloud-based server is supplied with metrics retrieved from smart gateways to find the most relevant and better performing gateways available for the IoT objects, creating and managing the logical clusters. The algorithm will use WiFi or LTE in order to increase the number of devices connected in clusters and improve the QoS metrics associated with the services provided by these devices.

Figure 3 illustrates NETSMITS' block level components, detailing the architecture described in Section III. Most important blocks are described next.

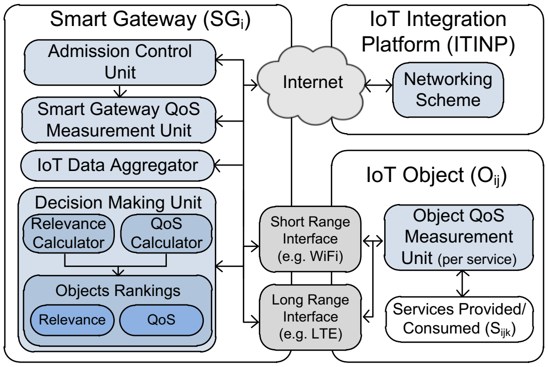


Fig. 3. NETSMITS - NETworking Scheme for sMart IoT gatewayS

A. *Utility functions*

NETSMITS employ two scores in its algorithms which will be presented later on in this paper: QoS and Relevance scores. Algorithmic notations are shown in Table I.

The *QoS score* is used for admission and performance control (i.e. a smart gateway with poor performance will request ITINP connecivity to a better performing gateway for new objects) and for ranking of objects (i.e. the objects with low performance are identified). The QoS score associated with an object is calculated by normalising the sum of the normalised values of each metric measured in the service provided by the object – see eq. (1). Then, an average of the service scores compose the QoS score of an object – see eq. (2). The formula in eq. (1) is also used to calculate the QoS score of a smart gateway.

$$Pijk = Norm\{\sum(\frac{Mx}{\max(Mx)})\}\ (1) \qquad Pij = avg(Pijk)\ (2)$$

The *Relevance score* is computed from an array of tuples composed by the gateways that have communicated with an object and the percentage of packets exchanged between each gateway and the object. For example, a device that has exchanged messages with two smart gateways has sent and received a total of 200 packets from devices in the same gateway (SG_1) and has sent and received a total of 400 packets from objects associated with a different gateway (SG_2). Therefore, $R_{ij} = \{[SG_1, 33{,}3\%], [SG_2, 66{,}6\%]\}$.

Algorithm 1 – Attaching low QoS-scoring objects

Require: List of P_{ij} per O_{ij} and R_{ij} in SG_i per O_{ij}

For each O_{ij}
  If SG_i **is not** most relevant SG
  and most relevant SG P_i >= SG_i P_i
    SG_i.detach(O_{ij})
    Most Relevant SG.attach(O_{ij})
  If O_{ij} **has** low P_{ij}
  and most relevant $SG = SG_i$
    SG_i.detach(O_{ij})
    Next most relevant SG.attach(O_{ij})

TABLE I
ALGORITHMIC NOTATIONS

Symbol	Definition
$M_{1\ldots n}$	Value of QoS metric of a service S_{ijk} (e.g. loss)
R_{ij}	Relevance Score of an object *ij*
I	ID of a Smart Gateway
J	ID of an Object
K	ID of a Service
ITINP	IoT Integration Platform
SG_i	Smart Gateway *i*
O_{ij}	Object *ij*
S_{ijk}	Service *ijk*
P_i	Performance Score of a smart gateway *i*
P_{ij}	Performance Score of an object *ij*
P_{ijk}	Performance Score of a service *ijk*
R_{ij}	Relevance Score of an object *ij*

B. *Major Architectural Components*

The *IoT objects' QoS Measurement Unit* collects QoS metrics per each service provided by the object (if the object is capable of running the algorithm). Values of these metrics are sent regularly to the smart gateway where they will be weighted, normalised and compose a QoS score. This paper considers *Throughput, Delay* and *Packet Loss Ratio* as QoS metrics.

The *Smart Gateway's Admission Control Unit* verifies if the gateway can support communication with a new object. If not, the object is associated to the next most suitable gateway, identified by ITINP. The Admission Control Unit procedure is triggered whenever a new object tries to register to a smart gateway.

The *Smart Gateways' QoS Measurement Unit* is similar to the IoT objects' QoS Measurement unit, retrieving the QoS metrics (per service) for the objects that are not capable of running the algorithm themselves. This unit also collects the smart gateways' related QoS metrics.

The *Decision Making Unit* is in charge with regular computation of QoS and Relevance scores, ranking of objects and deciding if they should be associated with another smart gateway or not. The QoS score calculator uses the utility functions from eq. (1) and eq. (2). The Relevance

TABLE II
SIMULATION SETUP

Parameter	Value
Simulator	NS-3.24.1
Duration of the Simulation	10s+10s before and after sim.
Distance between nodes and antennas	3m
WiFi Data Rate	40 Mbps
WiFi Standard	802.11ac (40MHz, MCS 9)
LTE eNB Antenna Model Type	Isotropic Antenna Model
LTE Data Rate	100 Mbps
Remote Station Manager	ConstantRateWifiManager
4K Video Bit Rate	25 Mbps
HDTV Bit Rate	10 Mbps
SDTV Bit Rate	4 Mbps
Other devices Bit Rate	1 Mbps

TABLE III
PERFORMANCE ANALYSIS OF NETSMITS

Devices	UL/ DL	Bit Rate [Mbps]	Phase 1 Netw.	Phase 1 Packet Loss [%]	Phase 1 Avg. Thru. [Mbps]	Phase 1 Avg. Delay [ms]	Phase 2 Netw.	Phase 2 Packet Loss [%]	Phase 2 Avg. Thru. [Mbps]	Phase 2 Avg. Delay [ms]	Phase 3 (SDTV + 19 devices on WiFi) Netw.	Phase 3 Packet Loss [%]	Phase 3 Avg. Thru. [Mbps]	Phase 3 Avg. Delay [ms]	Phase 4 (SDTV + 20 devices on WiFi) Netw.	Phase 4 Packet Loss [%]	Phase 4 Avg. Thru. [Mbps]	Phase 4 Avg. Delay [ms]
4K TV	DL	25	WiFi	8%	23.11	130.30	LTE	0%	25.58	10.00	LTE	0%	25.58	10.00	LTE	0%	25.58	10.00
HDTV	DL	10	WiFi	9%	9.51	130.25	LTE	0%	10.69	10.00	LTE	0%	10.69	10.00	LTE	0%	10.69	10.00
SDTV	DL	4	WiFi	10%	3.60	130.24	WiFi	0%	4.05	20.04	WiFi	0%	4.03	61.37	WiFi	2%	3.90	182.55
Device 1	DL	1	WiFi	0%	0.99	130.00	WiFi	0%	1.00	20.00	-	-	-	-	-	-	-	-
	UL	1		0%	1.01	0.59		0%	1.01	0.56	-	-	-	-	-	-	-	-
Device 2	DL	1	WiFi	1%	0.97	130.20	WiFi	0%	1.00	20.00	-	-	-	-	-	-	-	-
	UL	1		0%	1.01	0.56		0%	1.01	0.46	-	-	-	-	-	-	-	-
Device 3	DL	1	WiFi	13%	0.86	130.54	WiFi	0%	1.00	20.00	-	-	-	-	-	-	-	-
	UL	1		0%	1.01	0.76		0%	1.01	0.54	-	-	-	-	-	-	-	-
Device 4	DL	1	WiFi	41%	0.59	130.77	WiFi	0%	1.00	20.15	-	-	-	-	-	-	-	-
	UL	1		0%	1.01	0.66		0%	1.01	0.36	-	-	-	-	-	-	-	-
Device 5	DL	1	WiFi	71%	0.29	131.00	WiFi	0%	1.00	20.97	-	-	-	-	-	-	-	-
	UL	1		0%	1.01	0.59		0%	1.01	0.43	-	-	-	-	-	-	-	-
Avg. Rest of Devices	DL	1	-	-	-	-	-	-	-	-	WiFi	0%	1.00	64.43	WiFi	11%	0.88	183.95
	UL	1	-	-	-	-	-	-	-	-		0%	1.00	2.80		0%	0.99	3.01

score computation considers the number of packets exchanged with objects associated with diverse gateways. The scores are kept in a gateway database, which also stores the maximum metric values for the normalization process.

The *ITINP Networking Scheme* deploys a new algorithm (see Algorithm 1), which receives a list of poor performing objects and attaches them to better suitable gateways. The algorithm is triggered by the gateway Decision Making Unit.

V. PERFORMANCE ANALYSIS

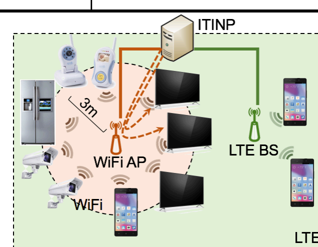
The simulation setup and NETSMITS' performance evaluation are presented in the next subsections.

A. Simulation Setup

The NETSMITS solution has been modelled and evaluated using Network Simulator 3 (NS-3). The model parameters are presented in Table II.

The scenario modelled is a smart house with many devices initially connected to a local gateway using a WiFi 802.11ac access point (fig. 4). Three of the devices are 4K, HD and SD TVs, which receive data at 25 Mbps, 10 Mbps and 4 Mbps. The remaining devices (labelled *other*) include smart appliances and phones, video monitoring equipment, laptops, etc. which both receive and send data at 1Mbps. Four phases are considered involving 5 *other* devices without and with NETSMITS deployment (phases 1 and 2), 19 and 20 *other* devices (phases 3 and 4), respectively.

NETSMITS regularly checks the delivery performance and suggests moving devices that are impacting performance to other gateways in the realm of ITINP to improve the quality of data delivery for all the devices. Without the presence of another gateway in the same WiFi network, the 4K and HD TVs will be reconnected to a



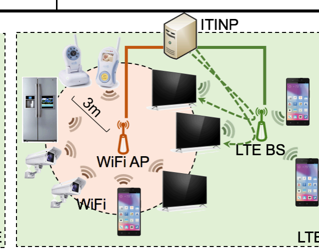


Fig. 4. Before running NETSMITS Fig 5. After running NETSMITS
Note: The arrows indicate the data path for the two affected devices only

gateway using LTE. The local gateway will then be able to accommodate more *other* devices (fig. 5).

B. Performance Evaluation

The results, available in Table III, show that after employing NETSMITS, the values of the QoS metrics improve, especially on the downlink (DL) of the devices. In phase 1, when all the devices are connected to the WiFi gateway, the packet loss ratio reaches up to 71% in one of the devices, and delay on the downlink is around 130ms. The highest throughput is not being achieved by any device, either. In phase 2, the innovative NETSMITS connectivity re-allocation happens. NETSMITS selected the 4K TV and the HDTV to be reattached to the LTE gateway. The results of phase 2 show that in the WiFi gateway packet loss is avoided, the highest throughput per device is achieved (fig. 6) and the delay is reduced by 85% (fig. 7). Phases 3 and 4 add more devices to the WiFi gateway. Two different tests are considered. Phase 3 demonstrates that 14 extra *other* devices with 1 Mbps bit rate each (an increase of 63% in number of devices) can be added without major QoS degradation. Phase 4 involves adding 15 extra *other* devices and results in some performance degradations, with an 185% increase of delay.

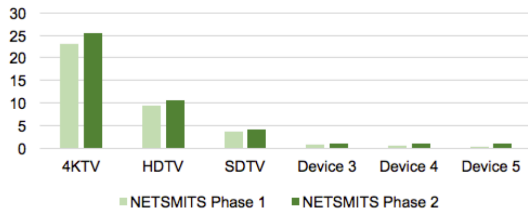


Fig. 6. Throughput. Comparison between NETSMITS phases 1 and 2

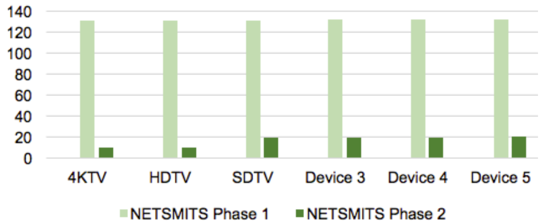


Fig. 7. Delay on the downlink. Comparison between NETSMITS phases 1 and 2

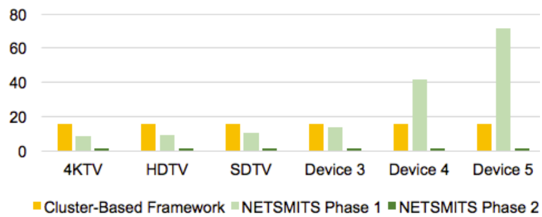


Fig. 8. Packet Loss Ratio. Comparison between the Cluster-Based Framework and NETSMITS phases 1 and 2

It can be seen how NETSMITS outperforms the Cluster-Based Framework, proposed in [18] having packet loss decreased from 15% in the framework, to zero in NETSMITS phase 2 (fig. 8). The Cluster-based Framework consists of a Wireless Mesh Network (WMN) where devices are clustered in order to improve QoS metrics in both static and mobile scenarios. The comparisons were made against the average values of the Cluster-based Framework static approach.

VI. Conclusions and Future Directions

This paper has introduced the Networking Scheme for Smart IoT Gateways (NETSMITS), which supports increased number of inter-communicating IoT objects and maintains higher quality of their offered services. NETSMITS employs assessing the values of QoS and Relevance metrics at the level of devices and gateways connected to a cloud-deployed IoT Integration Platform (ITINP). NETSMITS was assessed through NS-3 simulations and compared against another mechanism (i.e. Cluster-based Framework).

Results demonstrate that NETSMITS is able to avoid packet loss, allow highest throughput per device to be achieved and reduce delay by 85%, by rearranging devices in the available gateways. It also enables with 63% more devices to be connected to the better performing gateway.

Future work includes support for mobility to the devices as well as priority per device type.

Acknowledgment

This work was supported by the Irish Research Council grant number EPSPG/2015/178 and in part by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 688503 for the NEWTON project (http://newtonproject.eu).

References

[1] Goldman Sachs, "The Internet of Things: Making sense of the next mega-trend", Goldman Sachs, 2014. [Online]. Available: http://www.goldmansachs.com/our-thinking/outlook/internet-of-things/iot-report.pdf. [Accessed: 12- Apr- 2016].

[2] A. Noronha, R. Moriarty, K. O'Connell and N. Villa, "Attaining IoT Value: How To Move from Connecting Things to Capturing Insights", Cisco, 2016. [Online]. Available: http://www.cisco .com/c/dam/en/us/products/collateral/cloud-systems-management/ data-analytics/iot-whitepaper.pdf. [Accessed: 12- Apr- 2016].

[3] P. Biggs, J. Garrity, C. LaSalle, A. Polomska and R. Pepper, "Harnessing the Internet of Things for Global Development", International Telecommunication Union, 2016. [Online]. Available: https://www.itu.int/en/action/broadband/Docum ents/Harnessing-IoT-Global-Development.pdf. [Accessed: 14- Mar- 2016].

[4] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of Things for Smart Cities," *IEEE Internet Things J.,* vol. 1, no. 1, pp. 22–32, 2014.

[5] D. Guinard, V. Trifa, and E. Wilde, "A resource oriented architecture for the Web of Things," *IEEE Proc. Internet Things*, pp. 1–8, 2010.

[6] C. Mulligan and M. Olsson, "Architectural Implications of Smart City Business Models: An Evolutionary Perspective," *IEEE Commun. Mag*., vol. 51, no. 6, pp. 80–85, 2013.

[7] L. Mainetti, V. Mighali, and L. Patrono, "A software architecture enabling the web of things," *IEEE Internet Things J.*, vol. 2, no. 6, pp. 445–454, 2015.

[8] A. Hazmi, J. Rinne, and M. Valkama, "Feasibility study of IEEE 802.11ah radio technology for IoT and M2M use cases," *2012 IEEE Globecom Workshops 2012*, pp. 1687–1692, 2012.

[9] T. A. Butt, I. Phillips, L. Guan, and G. Oikonomou, "Adaptive and context-aware service discovery for the Internet of Things," *Proc. 13th Int. Conf. Next Gener. Wired/Wireless Adv. Netw. 6th Conf. Internet Things Smart Spaces)*, vol. 8121, pp. 36–47, 2013.

[10] N. Nasser, L. Karim, A. Ali, and N. Khelifi, "Multiple Base station and Packet Priority-based clustering scheme in Internet of Things," *Int. Conf. Comput. Manag. Telecomm. ComManTel*, pp. 58–61, 2014.

[11] L. Zou, R. Trestian, and G. M. Muntean, "EDOAS: Energy-aware device-oriented adaptive multimedia scheme for Wi-Fi offload," *IEEE Wirel. Commun. Netw. Conf. WCNC*, pp. 2916–2921, 2014.

[12] A. Castellani and M. Dissegna, "WebIoT: A web application framework for the internet of things," *IEEE Wirel. Commun. Netw. Conf. Work.*, pp. 202–207, 2012.

[13] A. Floris and L. Atzori, "Quality of Experience in the Multimedia Internet of Things: Definition and practical use-cases," *2015 IEEE Int. Conf. Commun. Work. ICCW 2015*, pp. 1747–1752, 2015.

[14] S. Ezdiani, I. S. Acharyya, S. Sivakumar, and A. Al-Anbuky, "An IoT Environment for WSN Adaptive QoS," *2015 IEEE Int. Conf. Data Sci. Data Intensive Syst*., pp. 586–593, 2015.

[15] S. Balasubramaniam and R. Jagannath, "A Service Oriented IoT Using Cluster Controlled Decision Making," *IEEE Int. Adv. Comput. Conf.*, pp. 558–563, 2015.

[16] S. Ghosh, "Mechanism for adaptive and context-aware inter- IoT communication," *2015 IEEE Int. Conf. Adv. Networks Telecommunications Syst*., pp. 1–6, 2015.

[17] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols and Applications," *IEEE Com. Surv. Tut.*, vol. 17, no. 4, pp. 2347-2376, 2015.

[18] J. Kim and J. Lee, "Cluster-based mobility supporting WMN for IoT networks," *Proc. - 2012 IEEE Int. Conf. Green Comp. Com. GreenCom,* pp. 700–703, 2012.