UDC 656.7.052 (045)

Agassi Melikov[1],
Anar Rustamov[1,2]

MEASUREMENT OF QoS METRIC OF MULTIMEDIA TRAFFIC CLASSES IN WIRELESS SENSOR NETWORKS

[1] **Inistitute of Cybernetics, Baku, Azerbaijan**
[2] **Qafqaz University, Baku, Azerbaijan**

WSNs require specific application designed for current phenomenon and based on some curtain quality of services (QoS) metrics. Unlike wired and mobile wireless networks, WSNs need totally different QoS measurement because of the resource limitation and low computational speed. In multimedia WSNs transferring of big-size video data is important factor for QoS metrics. Therefore effective buffer management systems are required in order to increase data transmission quality. In the paper, two types of multimedia classes- video and picture were analyzed and relative QoS model were proposed. The main measurement of the QoS metric is to decrease the probability of blocking of arrival packets. Furthermore, exact formula for the main indicator of the QoS measurement - Probability of Blocking is suggested. This model gives us clear understanding on selection of relevant specification of the microcontrollers and transceivers.

Introduction

Since wireless sensor networks (WSNs) based on different communication structure, development of micro-electro-mechanical systems (MEMS) opened new research and application areas. WSNs have limited hardware capability and unreplacable energy source. Moreover, WSNs require specific application designed for current phenomenon sensed.

Wireless sensor networks are consist of small sensor devices wirelessly connection to the each other. Secure and reliable data transmission is an integral part of the WSNs. These factors are mainly measured by encryption, time delay, error recovery and etc. Therefore routing protocols, path selections also affect reliable connection among sensor nodes. Although there are a number of researches on these areas, new application-specific-based routing protocols and path selection algorithms are required [1].

Complimentary Metal Oxide Semiconductor (CMOS) technologies extended range of application areas of WSNs. Based on new technologies it was able to transfer and store low quality video stream, still images, sounds and etc data via the sensor network [2].

Since sensor nodes have low computational speed, it affects the transferring of multimedia data through sensor nodes directly. Although the quality of video frames and pictures taken by these cameras is low, the size still becomes main challenges in transferring data. In this context WSNs require high bandwidth, where it results in additional energy consumption [3]. The higher quality, the higher utilization of resources takes place. Therefore Quality of Service (QoS) metrics should be included in multimedia WSNs in order to make trade-off between limited resources and quality measure. Moreover analyzing of multimedia data transfer on prolonging network life is one of the primary research areas of WSNs.

Because of resource limitation the software packages prepared for WSNs should be designed in according with the application area that depends on phenomenon to be observed. Moreover it will require specific quality metrics to measure quality of service (QoS) [10]. There are several factors that are directly connected to QoS metrics, such as short distance and low error rate. The bigger distance, the lower bandwidth and vice verse.

Sensor nodes are densely allocated and based on multi-hop communication. Sometimes high density results in latency and queue in each sensor nodes due to low computational speed [4]. Therefore new well designed and effective routing protocols are required in order to eliminate latency time of applications. In this regard, queueing of multimedia data in each node should be investigated deeply in order to diminish the energy consumption and prolong the network life.

The rest of the paper is organized as follows. In Section 2 a background of WSNs is given under the different topics- Multimedia WSNs, QoS in Internet, QoS in Mobile Wireless Networks and QoS in WSNs. In section 3 we proposed new framework of Queueing Theory based QoS measurement. Finally we do numerical result and conclusion in Section 4 and 5.

System Overview

Multimedia Wireless Sensor Networks

Wireless Sensor Network is composed of a number of tiny sensor devices. Each sensor device consists of sensor board and sensor mote. Sensor board is a device that is designed for observing a certain phenomenon. These devices are attached to sensor motes through the sensor boards. Sensor motes are composed of memory access control, processing unit, transmitter and programming board. Because of low energy consumption, low cost digital cameras are mostly used one in WSNs [5]. CMOS cameras are small sized and it uses less energy consumption that is integrated with sensor mote [6].

Quality Metrics in WSNs

Since sensor nodes have limited unreplacable energy resource, this issue became main factor in research related to routing protocol, path selection, queue and buffer management and etc. Unlike wired and mobile wireless networks, it is difficult to develop a common QoS mechanism to support less energy consumption. Moreover, QoS metric differentiates depending on the application area of the sensor networks. Therefore in WSNs, QoS mechanism should be individually analyzed and developed in respect with observed phenomenon [7].

Quality metric for WSN can be determined depending on different research area such as path selection, MAC layer protocol, queue ordering, error correction and etc. Particularly in multimedia WSNs there is required special routing protocol in order to remain picture quality high. For example, in some property areas in order to determine intruders the video cameras are maintained in different location through the wireless sensor nodes to get clear picture or video frame. For that reason a quality and accuracy of images/video frames should meet minimum level, where specific QoS is needed to be proposed.

In general, there are several common metrics for QoS support of WSNs on the bases of application area [8, 9] as below:

Energy efficiency: To prolong network life is of the key factor in WSNs. In this regard QoS metrics should be designed so that it would minimize energy usage and therefore maximize network life.

Network topology: Battery-depleted sensor nodes change the topology of sensor networks. Therefore network topology should be such deployed that if particular nodes fail, then neighboring sensing nodes are able to gather required information from observing phenomenon. However, densely deployed sensor nodes lead to data overlapping and hence, additional data traffic on network [10].

Coverage: Distribution of sensor nodes throughout the observation area affects coverage of the networks. If sensor nodes are densely allocated, then a number of hop counts become high. Therefore QoS metrics should consider how to avoid duplication of data [11].

Spatial accuracy: Depending on observation phenomenon, determination of location of the sensor nodes is required by the sink. There are several methods to define the location of the nodes [12, 13]. It is mainly based on Global Positioning System (GPS) or other calculation mechanisms. In these cases QoS metrics are used to the location with high accuracy.

Delay: Range of application area of WSNs can be categorized into three classes- query based, event-driven and periodic applications. In query based applications, the sink broadcast specific query and a sensor node, to which the query belongs, give response to the query. In event-driven application, sensor nodes gather data as phenomenon occurs and send them to the sink. In periodic applications, sensor nodes are activated periodically with the same interval and send the gathered data. QoS metrics used in delay fosters a data transfer between nodes and the sink.

Motivation and Proposed Framework

In this paper queue/buffer management in WSNs were analyzed based on big-sized multimedia. In particular, we focused on controlling and analyzing queue of packets that are sent from MAC layer to upper layers and of frames that arrives to Physical layers via medium. In the given model 2-channel system for transmission and receiving multimedia data as given in Fig. 1 were proposed. In the proposed model it is suggested that two types of data, *video* and *picture* data, will be received and transmitted via two different transceivers with arrival intensity λ_v and $\lambda_{p,}$ respectively.

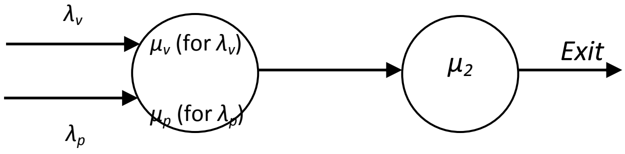

Fig 1. Structure of data flow in the given model.

At Physical layer each frame is served at the service intensity of μ_v for video packets and μ_p for picture packets. State diagram of the proposed model is given in Fig. 2. In this model seven states are available: (0, 0), $(1^{(v)},0)$, $(1^{(p)},0)$, (0,1), $(1^{(v)},1)$, $(1^{(p)},1)$, *b* (block). In idle mode system becomes in the state of (0, 0). When the first server receives a video or picture packets and serves them, the system goes to $(1^{(v)}, 0)$ or $(1^{(p)}, 0)$ state, respectively. In this case the second server should be idle. If the packet is forwarded to the second server to serve, then the system state becomes (0, 1), where the first server transits to idle mode. Other vise the system state will be in $(1^{(v)},1)$ or $(1^{(p)},1)$ state depending on video or picture packets. Namely both of the servers will be busy. The state *b* (blocking) happens when the first server is finished its task, but the second server is still in working regime. If the first serve is not idle, then arrival packet will be dropped.

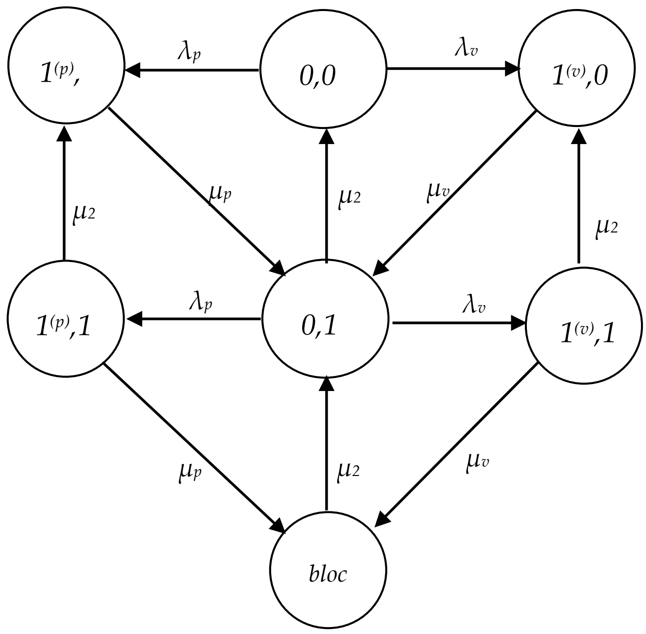

Fig. 2. The state diagram of the system.

Mathematical model for the given model can be expressed as below. Let $\pi(x)$ denote steady state probability of state x. A *balance equations* based on state probabilities for given model are calculated as given below:

$$\pi\ 0,0\ (\lambda_v + \lambda_p) = \pi\ 0,1\ \mu_2 \tag{1}$$

$$\pi\ 1^{(v)},0\ \mu_v = \pi\ 0,0\ \lambda_v + \pi\ 1^{(v)},1\ \mu_2 \tag{2}$$

$$\pi\ 1^{(p)},0\ \mu_p = \pi\ 0,0\ \lambda_p + \pi\ 1^{(p)}1,1\ \mu_2 \tag{3}$$

$$\pi\ 0,1\ \ \lambda_v + \lambda_p + \mu_2\ = \pi\ 1^{(p)},0\ \mu_p + \pi\ 1^{(v)},0\ \mu_v + \pi\ b\ \mu_2 \tag{4}$$

$$\pi\ 1^{(v)},1\ \ \mu_v + \mu_2\ = \pi\ 0,1\ \lambda_v \tag{5}$$

$$\pi(1^{(p)},1)(\mu_p+\mu_2) = \pi(0,1)\lambda_p \quad (6)$$

$$\pi(b)\mu_2 = \pi(1^{(v)},1)\mu_v + \pi(1^{(p)},1)\mu_p \quad (7)$$

Normalizing condition for the given system is:

$$\pi(0,0) + \pi(0,1) + \pi(1^{v},0) + \pi(1^{(p)},0) + \pi(1^{v},1) + \pi(1^{(p)},1) + \pi(b) = 1 \quad (8)$$

The state probabilities (π) can be determined as below by applying some mathematical calculation. From (1) we can get calculation of $\pi(0,1)$ as given in (9). By applying (9) to (5) and (6), we can get state probabilities $\pi(1^{(v)},1)$ and $\pi(1^{(p)},1)$ as given in (10) and (11), respectively.

$$\pi(0,1) = \frac{\lambda_v+\lambda_p}{\mu_2}\pi(0,0) = \rho_1\pi(0,0), \text{ where } \rho_1 = \frac{\lambda_v+\lambda_p}{\mu_2} \quad (9)$$

$$\pi(1^{(p)},1) = \frac{\lambda_p}{\mu_2+\mu_p}\pi(0,1) = \rho_2\rho_1\pi(0,0), \text{ where } \rho_2 = \frac{\lambda_p}{\mu_2+\mu_p} \quad (10)$$

$$\pi(1^{(v)},1) = \frac{\lambda_v}{\mu_2+\mu_v}\pi(0,1) = \rho_3\rho_1\pi(0,0), \text{ where } \rho_3 = \frac{\lambda_v}{\mu_2+\mu_v} \quad (11)$$

Taking into account (10) and (11) in (7), $\pi(b)$ can be obtained as follow:

$$\pi(b) = \frac{\mu_p}{\mu_2}\pi(1^{(p)},1) + \frac{\mu_v}{\mu_2}\pi(1^{(v)},1) = (\mu_p\rho_1\rho_2 + \mu_v\rho_1\rho_3)\pi(0,0) \quad (12)$$

Moreover (10) and (11) can be used in calculation of state probabilities $\pi(1^{(v)},0)$ and $\pi(1^{(p)},0)$.

$$\pi(1^{(v)},0) = \frac{\lambda_v}{\mu_v}\pi(0,0) + \frac{\mu_2}{\mu_v}\pi(1^{(v)},1) = \rho_4(1+\rho_5)\pi(0,0), \text{ where } \rho_4 = \frac{\lambda_v}{\mu_v};\ \rho_5 = \frac{\lambda_v+\lambda_p}{\mu_2+\mu_v} \quad (13)$$

$$\pi(1^{(p)},0) = \frac{\lambda_p}{\mu_p}\pi(0,0) + \frac{\mu_2}{\mu_p}\pi(1^{(p)},1) = \rho_6(1+\rho_7)\pi(0,0), \text{ where } \rho_6 = \frac{\lambda_p}{\mu_p};\ \rho_7 = \frac{\lambda_v+\lambda_p}{\mu_2+\mu_p} \quad (14)$$

Consequently, from normalizing condition (8) we get $\pi(0,0)$:

$$\pi(0,0) = (1+\rho_1+\rho_6+\rho_6\rho_7+\rho_4+\rho_4\rho_5+\rho_2\rho_1+\rho_3\rho_1+\mu_p\rho_1\rho_2+\mu_v\rho_1\rho_3)^{-1} \quad (15)$$

Here we are interested in the probability of blocking as a QoS Metric. In the proposed model the probability of blocking (*PB*) happens when the first server is busy and in the state of *blocking*. Eventually, we can calculate *PB* as below:

$$PB = \pi(1^{v},0) + \pi(1^{(p)},0) + \pi(1^{v},1) + \pi(1^{(p)},1) + \pi(b) \quad (16)$$

Based on the exact formulas of state probabilities, we did numerical analyses for the proposed model and find expected outcomes.

Numerical Results

In this paper probability of blocking (PB) of the system were analyzed as a QoS metric. Moreover, traffic classes such as video, sound, picture and streaming classes as a single multimedia class. The main factor in QoS measurement in WSNs is minimization of data loss. Numerical result of the proposed model is given in Figs. 4-10. Expected results satisfy the curves given in the graphs. In graphs relation of *PB* with $\mu_v, \mu_p, \mu_2, \lambda_p$ and λ_v is analyzed. Probability of blocking is positively related with the arrival intensity λ_v and λ_p. Indeed, as λ_v and λ_p are getting big values, a number of packets to be served by the server 1 are also getting increased. In Fig. 4 and 5 are given their relationship in different values of λ_p and λ_v, respectively (μ_v=20, μ_p=35, μ_2=25). The best option in minimizing blocking probability is to minimize λ_p or λ_v, respectively. As given in the Fig. 4 and 5 *PB* has lower value when $\lambda_p=5$ (for λ_v) and $\lambda_v=5$ (for λ_p), respectively.

To get a clear picture of dependence between *PB* and λ_p (and λ_v) depending on μ_v, μ_p and $\mu_2,$ we set the same values for them. As shown in Table 1, *PB* increases by decreasing rate as μ goes up. In Fig. 6 and 7 are also illustrated relationship of *PB* with λ_p and λ_v, respectively, where $\lambda_p=30$ and $\lambda_v=30$. $\mu_v=\mu_p=\mu_2=20$.

In Fig. 8-10 are given relationship of *PB* with μ_v, μ_p, μ_2, respectively. Blocking probability should be positively related to service intensities μ_v and μ_p. If to keep values of μ_2 fixed and increase values of μ_v and $\mu_p,$ a scale the *states of blocking* will be increased in server 2 (Fig. 8 and 9). In Fig. 8 curves were driven in different values of μ_p, where parameters were fixed constant (λ_v =60, λ_p =60, μ_2=25).). In Fig. 9 curves were also driven in different values of μ_v , where parameters were fixed constant (λ_v =60, λ_p =60, μ_2=25). But in Fig. 10 curves were driven in different values of μ_p and μ_v, where parameters were fixed constant (λ_v =60, λ_p =60). However, If to keep values μ_v and μ_p fixed and increase value of $\mu_{2,}$ then lost serving speed of packets will be increased, where it will result in decrease in probability of blocking of arrival packets. (Fig. 10).

Table 1. Comparison of Probability of Blocking (PB) in different values of μ (μ_1=μ_2=μ) depending on λ

λ	PB		
	μ=20	μ=30	μ=35
1	0.049	0.033	0.028
5	0.251	0.178	0.155
9	0.393	0.294	0.260
13	0.494	0.385	0.346
17	0.569	0.458	0.416
21	0.625	0.516	0.474
25	0.669	0.564	0.522
29	0.704	0.604	0.563
33	0.733	0.638	0.598
37	0.756	0.666	0.628
40	0.772	0.686	0.649

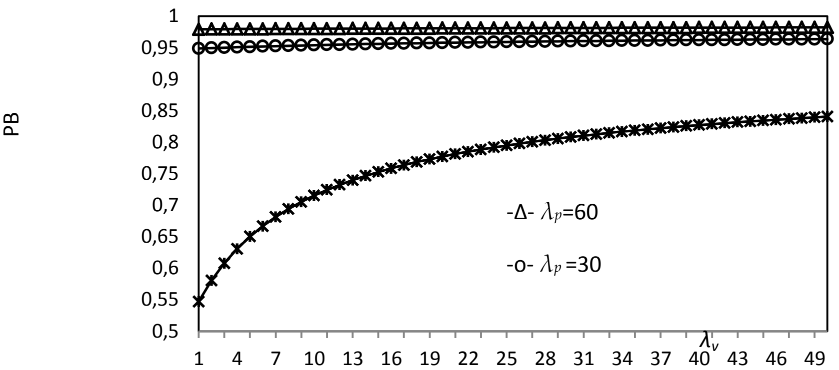

Fig. 4. Blocking probability of arrival packets versus λ_v

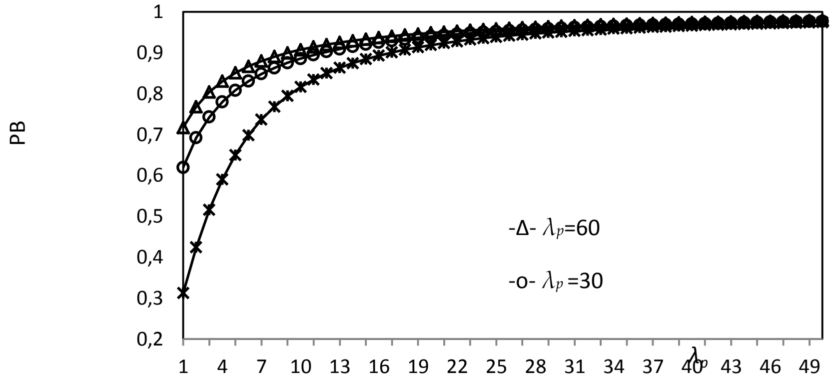

Fig. 5. Blocking probability of arrival packets versus λ_v

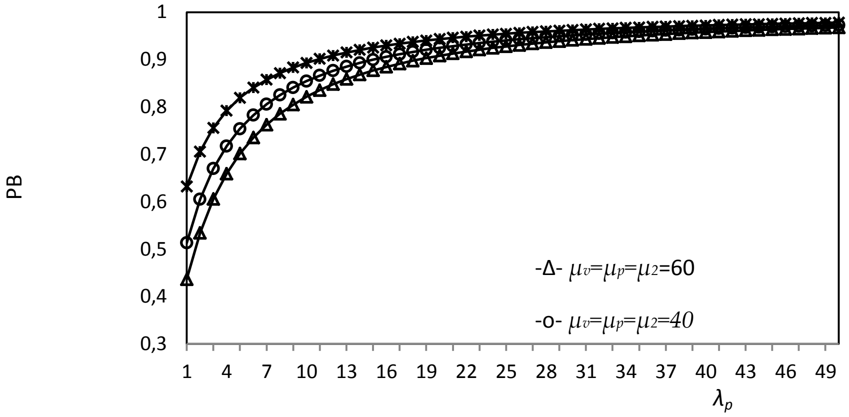

Fig. 6. Blocking probability of arrival packets versus λ_p

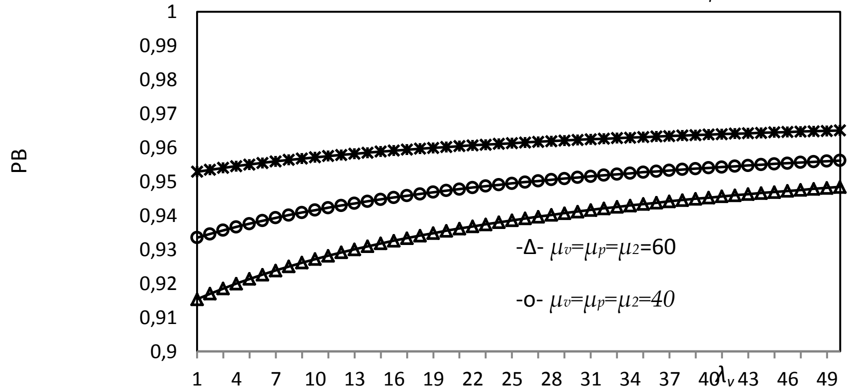

Fig. 7. Blocking probability of arrival packets versus λ_v

In Fig. 8 the blocking probabilities of the cases where μ_p=60 has a bigger values and implies that in order to decrease the data loss we should focus on small number of μ_p. The same behavior can be seen in Fig. 9 – relation of *PB* versus μ_p, so that the best result is given in the case of μ_v=10. In both cases the curves satisfy our expected results.

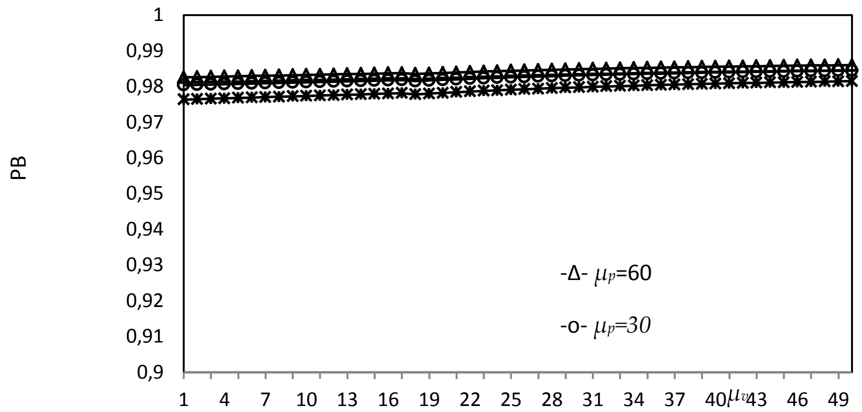

Fig. 8. Blocking probability of arrival packets versus μ_v

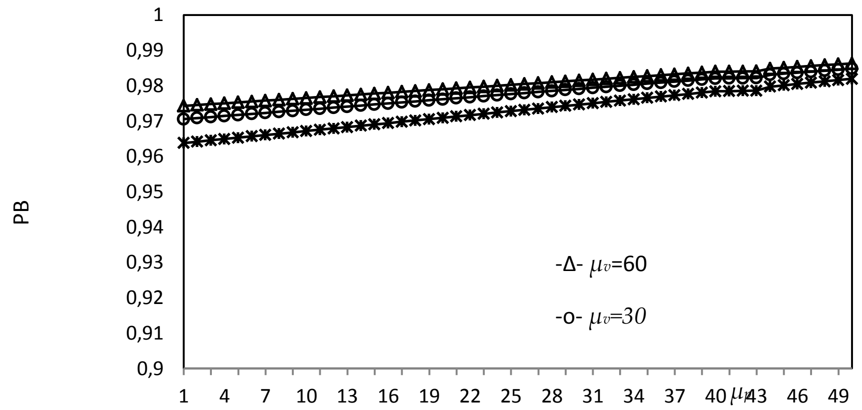

Fig. 9. Blocking probability of arrival packets versus μ_p

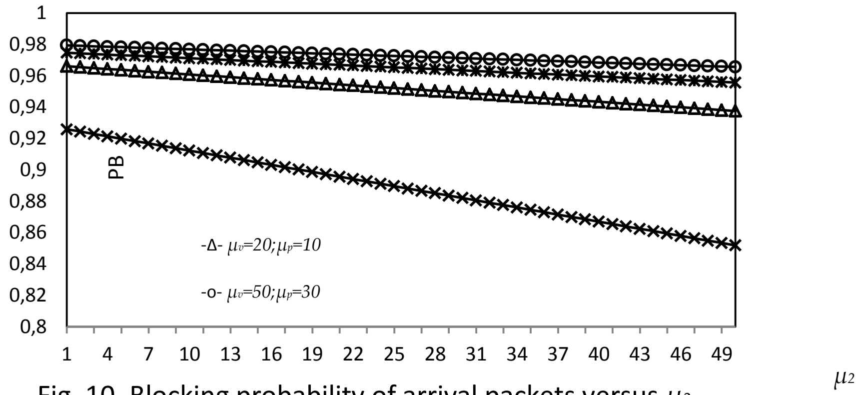

Fig. 10. Blocking probability of arrival packets versus μ_2

In order to make balance between service intensities of each server, selection of suitable microcontrollers plays main role in this context. Therefore, we analyzed relation between blocking probability and ratio of first and second server. Since size of video packet is bigger than picture packet, it is worth to analyze the intensity of video classes, μ_v, and μ_2 (μ_v/μ_2) (Fig. 11). For simplicity we set λ_v and λ_p equal and analyzed curves in three different values (λ_v=λ_p =50, λ_v=λ_p=70, λ_v=λ_p=100) and increased the values of μ_v and μ_2 based on the ratios as 0.25, 0.5, 0.75, …, 5. It is apparent from the figure that in the system there is always a blocking probability and the best choice is the minimum value of μ_v/μ_2. Therefore in selection of relevant microcontroller we should pick the one in which service intensity of the first server for video classes is less than second one or other vise in which service intensity of the second server is bigger than first one. The case of higher blocking probability when ratio of μ_v/μ_2 is bigger is reasonable, so that if the first server sends the packets with high intensity to the second server with low service intensity, then the second one cannot serve properly and therefore it will lead to data loss in the first server.

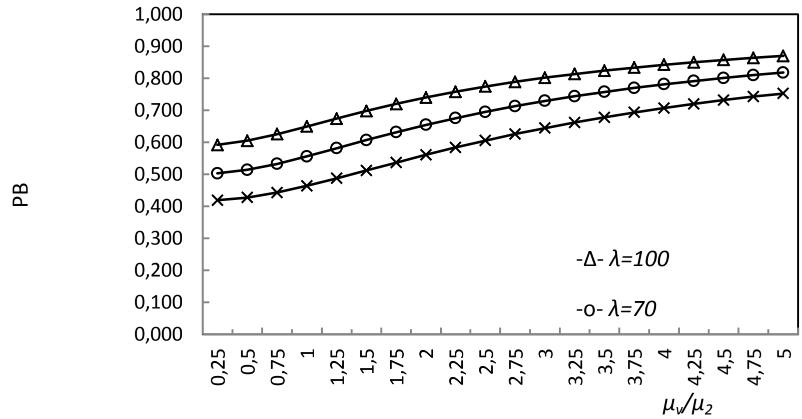

Fig. 11. Blocking probability of arrival packets versus μ_v/μ_2

Theoretically is known that the bigger the arrival intensity, the bigger data lost or the probability of blocking if to keep other parameters as constant. This phenomenon is obvious in Fig. 11 too, so that in the case of $\lambda_v=\lambda_p=50$ the probability of blocking is having the lowest values; however in the case of $\lambda_v=\lambda_p=100$ it has the biggest values.

Since a bufferless system is analyzed in the paper, it is important to note that selection of relevant and sufficient values of arrival and service intensities reasonably affects the cost of the microprocessor and transceivers. Furthermore, as a main factor of QoS in WSNs – longevity of the network should also be calculated based on the selected devices. It could be done by comparing the power supply of battery and required computational energy based on the selected device parameters.

Conclusion

In given article, Quality of Service (QoS) metrics in WSNs were analyzed. Available QoS measurement in wired network, mobile wireless networks are not suitable for sensor networks. For analyzing QoS metrics for multimedia WSNs, we took two types of multimedia classes-video and picture files. In this research we proposed Queueing Theory based QoS measurement for buferless system with two traffic classes in WSNs. We proposed exact mathematical formulas for calculation of the state probabilities and the probability of blocking and did numerical results. Proposed model gives us clear picture on how should server intensities be picked up in order minimize the probability of blocking.

References

1. M. Momani, J. Agbinya, G. P. Navarrete and M. Akache, “A New Algorithm of Trust Formation in Wireless Sensor Networks,” Proceedings of the 1st IEEE International Conference on Wireless Broadband and Ultra Wideband Communications, Sydney, March 2006.
2. I. F. Akyildiz et al., A survey on wireless multimedia sensor networks, Comput. Netw. (2006), doi:10.1016/j.comnet.2006.10.002
3. S. Misra; M. Reisslein; A survey of multimedia streaming in wireless sensor networks, IEEE Communications Surveys & Tutorials, vol. 10, no. 4, fourth quarter 2008
4. E. Magli, M. Mancin, and L. Merello, “Low-Complexity Video Compression for Wireless Sensor Networks,” in Proc. ICME 2003, vol. 3, July 003, P. 585-588.
5. P. Kulkarni, D. Ganesan, P. Shenoy, The case for multi-tier camera sensor network, in: Proc. of the ACMWorkshop on Network and Operating System Support for Digital Audio and Video (NOSSDAV), Stevenson, WA, USA, June 2005.
6. I. F. Akyildiz , Mehmet Can Vuran, Wireless Sensor Networks, John Wiley and Sons Publication, 2010.
7. Z.A. Boukerche; R.B. Araujo; Villas, L. A Wireless Actor and Sensor Networks QoS-Aware Routing Protocol for the Emergency Preparedness Class of Applications. In Proc. 31st IEEE Conf.on Local Computer Networks, Tampa, FL, 2006, P. 832-839
8. E. Felemba; C. Lee; E. Ekici, MMSPEED: Multipath Multi-SPEED protocol for QoS guarantee of reliability and timeliness in wireless sensor networks. IEEE Transactions on Mobile Computing 2007, 5(6), P. 738-754
9. X.T. Hwee, Quality of Service in Wireless Sensor Networks, IEEE Communications Magazine, Jan., 2005.
10. N. Heo and P. K. Varshney, Energy-Efficient Deployment of Intelligent Mobile Sensor Networks, IEEE Transactions on Systems, Man and Cybernetics, Vol. 35, No. 1, Jan 2005.
11. L. Hu and D. Evans, Localization for Mobile Sensor Networks, Proceedings of the 10th Annual International Conference on Mobile Computing and Networking (ACM Mobicom ’04), Philadelphia, PA, USA, 26 Sep – 1 Oct, 2004.
12. N. B. Priyantha, H. Balakrishnan, E. Demaine and S. Teller, Mobile-Assisted Localization in Wireless Sensor Networks, Proceedings of the 24th Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM 2005), Miami, FL, Mar 13 – 17, 2005.
13. A. Savvides, C.-C. Han and M. B. Srivastava, Dynamic Fine-Grain Localization in Ad-Hoc Networks of Sensors, Proceedings of the 7th Annual ACM/IEEE International Conference on Mobile Computing and Networking (Mobicom ’01), 2001.
14. D. Malan, T. Fulford-Jones, M. Welsh, and S. Moulton. CodeBlue: an Ad Hoc sensor network infrastructure for emergency medical care. In Proceedings of Workshop on Applications of Mobile Embedded Systems (WAMES2004), Boston, MA, USA, June 2004.
15. W. D. Gustavo, H. B. Carlos., Alexandre C., Ricardo N.P., A geographic routing hybrid approach for void resolution in wireless sensor networks, The Journal of Systems and Software 84 (2011), 2011, P. 1577–1590.