Maximizing clusters lifetime in Mobile Wireless Sensor Networks

Tarek Moulahi[1,2,3], Salem Nasri[2] & Hervé Guyennet[3]
[1]CBE, Qassim University, Al-Qassim, KSA
[2]ENIS, University of Sfax, Sfax, Tunisia
[3]University of Besançon, Besançon, France
tarek.moulahi@lifc.univ-fcomte.fr, salem.nasri@enim.rnu.tn
herve.guyennet@lifc.univ-fcomte.fr

ABSTRACT
Clustering is an organizational approach which has been applied over flat Wireless Sensor Networks (WSNs) to induce a hierarchical structure. In clustered WSNs the communication overheads and the energy consuming are minimized. In addition, network tasks like routing, data aggregation as well as networks self-reconfiguration are more easy. Although many previous efforts, clustering in mobile WSNs (MWSNs) is always a challenging problem due to the dynamic topology of the network and the limit of sensor resources. In this paper, we propose a new scheme to maximize clusters lifetime in MWSNs which is based on link lifetime between mobile sensors. Performances of the proposed method are measured through a simulation study using NS-2.

General Terms
Algorithms, Measurement, Performance.

Keywords
Mobile Wireless Sensor Networks, Clustering, lifetime, evolutionary graph.

1. INTRODUCTION
A sensor is an autonomy device able to sense, to compute and to communicate wirelessly with other sensors. Furthermore, a sensor is characterized by its low cost which makes it useful for many fields like military and environment monitoring [1,2].

The most disadvantages of a sensor are its limit memory, bandwidth and computing capacity besides its limit energy .A set of sensor forms a Wireless Sensor Networks (WSNs) which is based on a collaborative work of the sensors and has a special node called sink node which is the getaway to the digital world.

In most cases, sensors are deployed randomly in unmonitored field. Consequently, the task of organizing and communicating between sensors is a challenging problem. On the other hand, many applications require mobile sensors as example for monitoring some animals in forest. Thus, it becomes very important to resolve the problem of communication between mobile sensors in MWSNs.

A flat WSNs is the natural formation of WSNs after its deployment using radio links. The clustering is one of the organizing approach with is applied on flat WSNs to induce a hierarchical structure. In this organizing approach a sensor will become either a cluster head "CH" or a cluster member "CM" which is belonged to a cluster head. All cluster heads are linked to each other for forming a backbone which is itself linked to the sink node. The clustering helps to reduce communications overheads which decrease the energy consuming. Consequently, clustering approach increase networks lifetime. The other important advantage of clustering is the data aggregation which is a fundamentals task for data gathering.

Many clustering scheme have been proposed in the literature for WSNs. LEACH (Low-Energy Adaptive Clustering Hierarchy) proposed in [3] was one of the first scheme aiming to use clustering approach to extend network lifetime. Since that LEACH have been enhanced many times we discuss LEACH improvement in the related work section specially enhancements which take into consideration the mobility behavior of sensors.

Most clustering scheme in MWSNs are based on LEACH enhancement which requires an immense number of exchanged messages to elect cluster-head for an undefined architecture lifetime. Our approach is based on maintaining as much as possible an architecture by defining lifetime for clusters. So, we propose a new scheme which is performed in two phases. In phase 1, we use a method to compute link lifetime between sensors. Next, in this paper sensors will be replaced by node and link between sensors will be replaced by the term edge. The phase 2 of our scheme will select cluster head and their appropriate cluster member by enhancing an idea proposed in [4] for creating Connected Dominating Set (CDS) with maximum lifetime.

The reminder of this paper is organized as follow. Section 2 outlines the most scheme and protocols for creating clusters in both WSNs and WMSNs. In section 3, we present our contribution that defines lifetime for clusters. Section 4 concerns a simulation study of our proposed method. Finally a recap of this paper is given in section5.

2. RELATED WORKS

Many efforts have been made by the scientific community to transform an unstructured WSNs to a structured network using clustering. In fact, clustering provide a hierarchical organization of WSNs. Furthermore, the clustering architecture allows routing, data aggregation and any type of communication between node with minimum cost in term of overheads and energy consuming. The process of clustering, in most cases, is beginning by selecting a set of sensors to be cluster heads which are linked to each other or linked through getaways. One or more than one cluster head is linked to the base station according to the adopted architecture. The selection of cluster head is performed according to many factors like the maximum remaining energy, the minimum velocity and the position of nodes. After selecting the appropriate cluster heads, the remains of sensors will be identified as cluster members and each one of them will choose autonomously its appropriate cluster head.

In the literature LEACH [3] is one of the first proposed protocols which is based on using clustering to extend network lifetime. In this method, cluster heads are selected randomly by using a probability and the consideration of node remaining energy. LEACH protocols is designed for a static WSNs. In [5], there are an evaluation of LEACH with MWSNs. In fact, authors study the effect of mobility on the packet lose ratio of LEACH protocol. So, they propose a geometric solution for the evaluation of links reliability between cluster head and cluster member.

Many enhancement of LEACH have been introduced to improve its performance with MWSNs. In [6], there is a proposition of LEACH-ME (LEACH Mobile Enhance protocol), which improve LEACH by taking into account the mobility metric when electing cluster heads. LEACH-M (LEACH mobile) have been proposed in [7] in order to support node mobility. As well as LEACH, LEACH-M use the same setup phase. The main idea of LEACH-M is to check if a mobile node is able to communicate with a specific cluster head. This checking is performed by transmitting a message which requests for data transmission back to mobile sensor node from cluster head within a time slot allocated in TDMA schedule of a cluster. By the end, the authors of [7] have demonstrated, through a simulation study, that LEACH-M enhance LEACH by reducing the loss of data packet for mobile nodes but with an amount of energy more superior.

CES (Cluster-based Energy-efficient Scheme) [8] is another LEACH based clustering scheme for MWSNs. CES is based on the use of nodes weights including k-density. Authors defined The k-density of a node *u* as a ratio between the number of links in its k-hop neighborhood and the k-degree of *u*. Through simulations study, CES has improved both LEACH and LEACH-C [9] in term of the total amount of data received at the sink node.

M-LEACH [10] (Mobile LEACH) is another primitive of LEACH. In fact, Nguyen et al. describes the disadvantage of LEACH by testing it with mobile sensors. So, they propose M-LEACH by taking into consideration the node position and the node velocity when selecting cluster head. Furthermore, remaining energy is an important factor during the invitation phase when cluster member select their appropriate cluster heads. A simulation study shows that M-LEACH outperforms LEACH-C in term of dealing with node mobility. Nevertheless, M-LEACH consider only the mobility of sensor with a fixed sink node.

In [11], Kim introduce a new clustering scheme for data aggregation in MWSNs basing on LEACH approach. The proposed method is performed in two phases. During phase 1, each node compute its potential score which is based on the similarity of movement, node remaining energy and density. Each node decide autonomously to be a cluster head according to its potential score. In phase 2, the member nodes choose its appropriate cluster head according to link lifetime and the amount of energy for transmitting gathered data.

According to this literature review, we can conclude that the most of clustering algorithms are based on LEACH scheme. The most disadvantage of such a way is the big number of exchanged message to select cluster head or to determinate the appropriate cluster head for each cluster member. In this paper we present a novel point of view to define a cluster architecture to MWSNs. Our scheme is performed in two phases. In phase1, each node send its actual position, its final position and its velocity. In phase 2, we define a method to compute links lifetime between each couple of node, and using an enhancement of a recent method defined in [4] the sink node define a cluster architecture and broadcast it to the whole network.

3. CONTRIBUTION

This section is divided in five subsections. First, we give our network model. Next, we define a method to compute link lifetime between sensors. Then, our proposed scheme is given as well as an illustration example. Finally we define a generalization of our scheme.

3.1 Network model

In this paper:

- A MWSNs is represented by a temporary weighted graph *Gt(V,E,t)* where *V* is the set of sensor node and *Et* the set of edge (links) between nodes. The weight of each edges between two nodes is the lifetime of the link between the same nodes represented by *t*.
- The sink node is stationary.
- All other nodes are similar with the same radius of transmission which is the same also for the sink.
- Each node have a localization system to determinate its position and its velocity.

3.2 Link lifetime between sensor nodes

An illustration of node movement is performed in figure1.

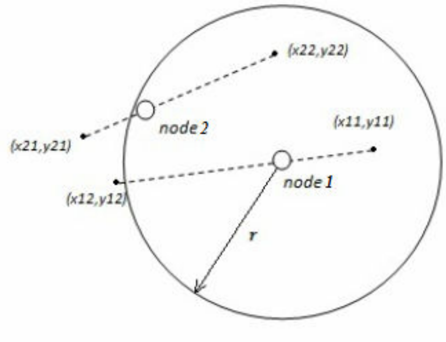

Figure 1. Illustration of nodes movement

Suppose that two nodes *node1* and *node2* are within the transmission range of each other(see figure 1), and suppose that *v1* is the velocity of *node1* from *(x11; y11)* to *(x12; y12)* and *v2* the velocity of *node2* from *(x21; y21)* to *(x22; y22).*

In the following we compute the lifetime of the edge between *node1* and *node2* .

The mobility of any nodes according to the time *t* can be represented by the equation:

$$\overrightarrow{X(t)} = \overrightarrow{V}t + \overrightarrow{X_0} \qquad (1)$$

Where:

$\overrightarrow{V}$ is the node velocity,

and $\overrightarrow{X_0}$ is the node initial position.

So, the mobility of *node1* follows the equation:

$$\overrightarrow{X_1(t)} = \begin{cases} x = a_1 t + x_{11} \\ y = b_1 t + y_{11} \end{cases} \qquad (2)$$

And, the mobility of *node2* follows the equation:

$$\overrightarrow{X_2(t)} = \begin{cases} x = a_2 t + x_{21} \\ y = b_2 t + y_{21} \end{cases} \qquad (3)$$

With,

$$a_1 = \frac{v_1(x_{12} - x_{11})}{\sqrt{(x_{12} - x_{11})^2 + (y_{12} - y_{11})^2}} \qquad (4)$$

$$b_1 = \frac{v_1(y_{12} - y_{11})}{\sqrt{(x_{12} - x_{11})^2 + (y_{12} - y_{11})^2}} \qquad (5)$$

$$a_2 = \frac{v_2(x_{22} - x_{21})}{\sqrt{(x_{22} - x_{21})^2 + (y_{22} - y_{21})^2}} \qquad (6)$$

And,

$$b_2 = \frac{v_2(y_{22} - y_{21})}{\sqrt{(x_{22} - x_{21})^2 + (y_{22} - y_{21})^2}} \qquad (7)$$

Let *r* the radius of transmission of *node1*. Maintain the edge between *node1* and *node2* in life means that the distance between the two nodes is less than *r*. This fact can be written as follow:

$$\|\overrightarrow{X_1(t)} - \overrightarrow{X_2(t)}\| \preceq r \qquad (8)$$

Which is equivalent to:

$$\sqrt{(x_{node_1} - x_{node_2})^2 + (y_{node_1} - y_{node_2})^2} \preceq r \qquad (9)$$

Equivalent to:

$$\alpha t^2 + \beta t + \gamma \preceq 0 \qquad (10)$$

Where:

$$\alpha = (a_2 - a_1)^2 + (b_2 - b_1)^2 \qquad (11)$$

$$\beta = 2(a_2 - a_1)(x_{21} - x_{11}) + 2(b_2 - b_1)(y_{21} - y_{11}) \qquad (12)$$

And

$$\gamma = (x_{21} - x_{11})^2 + (y_{21} - y_{11})^2 - r^2 \qquad (13)$$

On the other hand the final position of *node1* is (x12; y12) and the final position of *node2* is (x22; y22) i.e.,

$$0 \prec t \preceq Min\left(\frac{\sqrt{(x_{12} - x_{11})^2 + (y_{12} - y_{11})^2}}{v_1}, \frac{\sqrt{(x_{22} - x_{21})^2 + (y_{22} - y_{21})^2}}{v_2}\right) \qquad (14)$$

Finally, we can easily find the lifetime of the edge between *node1* and *node2* , which is the period of time verifying the equation 14.

3.3 Mobile clustering scheme

Our scheme is performed in two phases. In phase one, each node send a packets containing its position and its velocity to the sink. In phase two, the sink node create the temporary weighted graph *Gt(V,E,t)*. Next, the algorithm of maximum lifetime proposed in [4] is applied to get *Gt2* which is a connected subgraph of *Gt*. Finally, clustering scheme is executed.

Algorithm1 : Mobile Clustering Scheme

INPUT: A set of packets containing nodes initial position, nodes final position and nodes velocity.
OUTPUT: A set of cluster heads *CH*, sets of cluster member for each cluster head CM_i and the set of gateways between cluster heads *GW*

1: Create *Gt(V,E,t)* weighted by edge lifetime
2: *Gt2(V,E2,t2)*=**MaxLifetime**(*G*) // *procedure from* [4]
3: {*CH,CMi*}=**Clustering**(*Gt2*) // *to be given in algorithm 2*
4: Broadcast node identifiers in the network.

In algorithm2, we present our method to select cluster heads and their members.

Algorithm2 : Clustering Procedure

INPUT: A Graph *Gt(V,E,t)*
OUTPUT: A set of cluster heads *CH* and sets of cluster members for each cluster head CM_i

1: Sort nodes from *V* in descending order according to their degree and put them in *Vd* ={*vd1,vd2….,vdn*}.
2: *CH*={*sink* }
3: **FOR** i from 1 to | *Vd* |
4: *CH=CH* ∪ *vdi*
5: **IF** nodes in *CH* are connected **AND** nodes in *V* \ *CH* are at least linked to one node in *CH* **THEN** **Break**
6:**END FOR**
7: **FOR ALL** node *ch* in *CH* //*optimization*
8: **IF** the set *CH*\{*ch*} still connected **AND** nodes in *V* \ *CH* are at least linked to one node in *CH* **THEN**
9: *CH=CH\{ch}*
10: **END FOR ALL**
11: **FOR ALL** node *cm* in *V* \ *CH* //*cluster members*
12: select the set *CHt* where *cm* can be linked
13: choose *chi* in *CHt* having minimum cluster member
14: *CMi=CMi* ∪ *{cm}*
15: **END FOR ALL**

3.4 Illustration

In this section, we make an illustration of our proposed method. In figure 2, we give the graph *Gt(V,E,t)* after edges lifetime calculation. In figure 3, we give the same graph after applying *MaxLifetTime* procedure. Next, figure 4 represents the cluster heads selection. Finally, figure 5 describes the cluster members selection of each cluster heads.

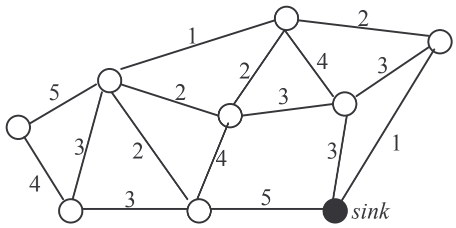

Figure 2. Example of a network weighted by edge lifetime

MaxLifetime procedure start by edges with small weight and eliminates them if their elimination don't affect the graph connectivity. This procedure ends when it can't eliminate.

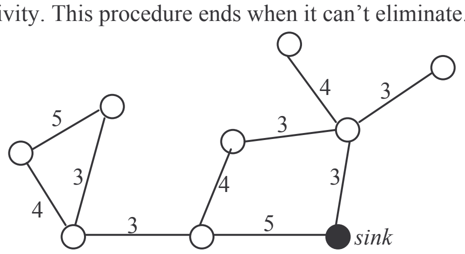

Figure 3. Applying *MaxLifeTime* procedure

The selection of cluster heads is started by node having maximum degree. This procedure is ended when all cluster heads are connected and the other nodes in the graph are linked to at least one cluster head.

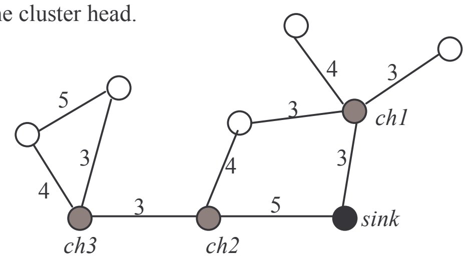

Figure 4. Selection of cluster heads

The affectation of cluster members to their appropriate cluster heads is done according to: each cluster member has only one cluster head, and if it can be linked to more than one it chooses the cluster head with minimum cluster members.

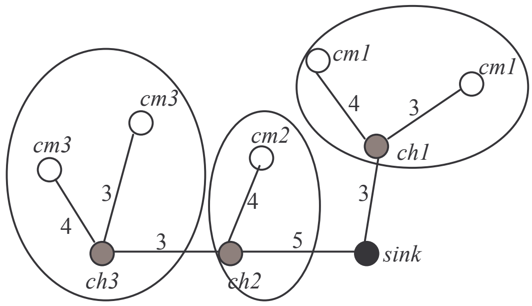

Figure 5. Affectation of cluster members to cluster heads

3.5 Generalization

In this subsection, we present a generalization of our scheme to be applicable with a list of sensors mobility scenarios. Our idea is to transform a mobile situation to a list of static situations having each one a lifetime as shown in the evolutionary graph below:

$$\mathcal{G}= \{G0(V,E0,t0);\ G1(V,E1,t1); \ldots\ldots ;Gn(V,En,tn)\}$$

Where:

- *V*: the set of nodes which is always the same,
- *Ei*: the set of temporary edges between nodes,
- *ti*: the minimum edge lifetime of the graph after applying *MaxLifeTime* procedure.

After creating a list of static graphs having each one a defined lifetime the clustering architecture of MWSNs can be selected using our proposed scheme as follow:

$$\mathcal{G}\text{clustered}=\{(CH0,CMi0,t0);(CH1,CMi1,t1); \ldots;\ (CHn,CMin,tn)\}$$

Where:

- *CHi*: is the set of cluster heads of the graph *Gi(V,Ei,ti)*,
- *CMij*: is the set of cluster members belonging to the cluster heads *CHj* in the graph *Gi(V,Ei,ti)*,
- *ti*: is the clustering lifetime.

4. SIMULATION STUDY

In this section, we make a simulation study using NS2[12], and according to table 1.

The simulation is executed five times and next w consider the average. We suppose that nodes change their direction and their velocity every 60 seconds.

Table 1. Simulation parameters

Parameters	Value
Network size	500*500 m
Deployment	Random and connected

Number of nodes	50,100,150,200,250,300
Radius of transmission	50m,100m
Node velocity	1m/s, 5m/s
Simulation duration	60 seconds

In figure 6, we maintain a velocity equal to 1m/s, and we measure the clustering lifetime for nodes with 50 m as radius of transmission and next for 100 m. We can see that the cluster lifetime is an average equal to 60% of the total simulation duration. Consequently, the whole simulation need in average two different clustering architectures i.e. we have to execute our scheme 2 times during the total duration of simulation time.

In figure 7, we choose a velocity of 5m/s, and we measure the clustering lifetime for nodes with 50 m as radius of transmission and next for 100 m. We can see that the cluster lifetime is an average equal to 35% of the total simulation duration. Consequently, the whole simulation need in average four or five different clustering architectures i.e. we have to execute our scheme between 3 and 4 times during the total duration of simulation time.

As notice, in this simulation we have supposed that nodes change their directions and their velocities every 60 seconds. So, if this duration is greater our scheme will perform better.

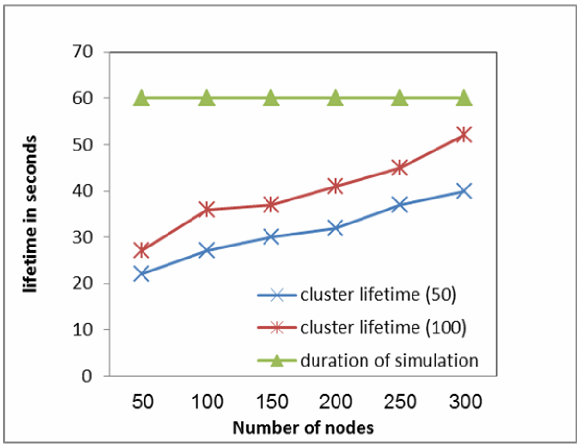

Figure 6. Clusters lifetime for a velocity = 1 m/s.

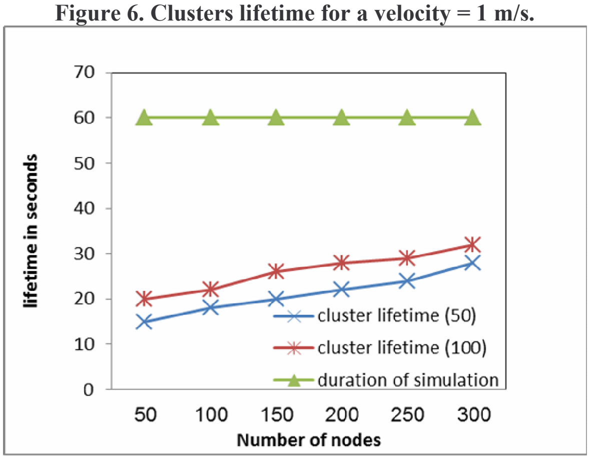

Figure 7. Clusters lifetime for a velocity = 5 m/s

5. CONCLUSION

In this paper, we have proposed a new scheme for clustering in MWSNs based on edge lifetime. The most of previous works aimed to maximize network lifetime by extending node lifetime. This fact have been realized by choosing node with minimum velocity and with maximum energy. Our point of view is to extend network lifetime by extending as much as possible clustering lifetime. This is in order to avoid the re-execution of clustering method that need a big number of exchanging messages to be realized. We have also present a generalization of our scheme based on evolutionary graph. A future work can focuses on making extensive simulations and comparisons between our approach and LEACH family protocols.

6. REFERENCES

[1] YICK, Jennifer, MUKHERJEE, Biswanath, et GHOSAL, Dipak. Wireless sensor network survey. *Computer networks*, 2008, vol. 52, no 12, p. 2292-2330.

DOI=http://dx.doi.org/10.1016/j.comnet.2008.04.002

[2] AKYILDIZ, Ian F., et al. Wireless sensor networks: a survey. *Computer networks*, 2002, 38.4: 393-422.

DOI= http://dx.doi.org/10.1016/S1389-1286(01)00302-4

[3] HEINZELMAN, Wendi Rabiner; CHANDRAKASAN, Anantha; BALAKRISHNAN, Hari. Energy-efficient communication protocol for wireless microsensor networks. In: *System Sciences, 2000. Proceedings of the 33rd Annual Hawaii International Conference on*. IEEE, 2000. p. 10 pp. vol. 2.DOI= http://dx.doi.org/10.1109/HICSS.2000.926982

[4] LIN, Zhiyong, et al. Constructing Connected-Dominating-Set with Maximum Lifetime in Cognitive Radio Networks. 2013. DOI= http://dx.doi.org/10.1109/TC.2013.77

[5] NAYEBI, Abbas; SARBAZI-AZAD, Hamid. Performance modeling of the LEACH protocol for mobile wireless sensor networks. *Journal of parallel and distributed computing*, 2011, 71.6: 812-821.

DOI= http://dx.doi.org/10.1016/j.jpdc.2011.02.004

[6] KUMAR, G. Santhosh; PAUL, Vinu; JACOB, K. Poulose. Mobility metric based leach-mobile protocol. In: *Advanced Computing and Communications, 2008. ADCOM 2008. 16th International Conference on*. IEEE, 2008. p. 248-253.

DOI= http://dx.doi.org/10.1109/ADCOM.2008.4760456

[7] KIM, Do-Seong; CHUNG, Yeong-Jee. Self-organization routing protocol supporting mobile nodes for wireless sensor network. In: *Computer and Computational Sciences, 2006. IMSCCS'06. First International Multi-Symposiums on*. IEEE, 2006. p. 622-626.

DOI= http://dx.doi.org/10.1109/IMSCCS.2006.265

[8] LEHSAINI, Mohamed; GUYENNET, Hervé; FEHAM, Mohammed. CES: Cluster-based energy-efficient scheme for mobile wireless sensor networks. In: *Wireless Sensor and Actor Networks II*. Springer US, 2008. p. 13-24.

DOI= 10.1007/978-0-387-09441-0_2

[9] HEINZELMAN, Wendi B.; CHANDRAKASAN, Anantha P.; BALAKRISHNAN, Hari. An application-specific

protocol architecture for wireless microsensor networks. *Wireless Communications, IEEE Transactions on*, 2002, 1.4: 660-670. DOI= http://dx.doi.org/10.1109/TWC.2002.804190

[10] NGUYEN, Lan Tien, et al. An energy efficient routing scheme for mobile wireless sensor networks. In: *Wireless Communication Systems. 2008. ISWCS'08. IEEE International Symposium on*. IEEE, 2008. p. 568-572. DOI= http://dx.doi.org/10.1109/ISWCS.2008.4726120

[11] KIM, Hyunsook. An Efficient Clustering Scheme for Data Aggregation Considering Mobility in Mobile Wireless Sensor Networks. *International Journal of Control & Automation*, 2013, 6.1. DOI=

[12] The Network Simulator - ns-2, http://www.isi.edu/nsnam/ns