An Efficient Distributed Broadcasting Algorithm based on Cross Layer Design for Ad Hoc Networks*

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Abstract - *In this paper we propose a broadcast algorithm for Ad hoc Networks based on Cross-Layer design concept. It improves the broadcasting mechanism in the wireless Ad hoc networks. We modify Joint Distance Counter Threshold (JDCT) protocol to implement our algorithm called Adaptive Distance Counter Threshold Algorithm (ADCT). The algorithm runs in a distributed manner by each node in the network without needing any global information. Each node in an ad hoc network uses the parameters of Physical layer and Network layer and makes a scheduling decision by using these parameters. Local adaptation of these parameters to achieve required results improves broadcasting decisions by altering the directed topology graph, feasible transmission schedules, and payload transmission rates. The simulations results demonstrate that ADCT algorithm based on the Cross-Layer information has better reachability, less latency and greater throughput*

Keywords: Cross-Layer, Ad hoc Networks

1 Introduction

Traditional layered approaches designed for wired networks cannot work at all or work poorly when we use it with wireless networks. Recently, there has been a lot of research on cross layer approaches where the traditional layering of the network protocol stack is going on to facilitate interactions between layers.

The research of routing is still at the beginning and some routing protocols have been put forward [1-8] in mobile ad hoc networks. Most of these protocols depend on a broadcast mechanism [9-11].

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Various efficient broadcast mechanisms have been proposed for MANET but they mostly depend upon the topology or neighborhood information.

There are also many distributed broadcasting algorithms with no use of global information have been proposed for use. But so far, no generic framework can capture a large body of distributed Broadcast Algorithm.

Our approach to solve flooding problem is to introduce the PLM (Physical Layer Metrics) and NLM (Network Layer Metrics) in the scheduling decision of each node. Our efficient adaptive distance-counter threshold algorithm is similar to JDCT described in [12]. But JDCT uses fixed distance threshold and our proposed algorithm calculate the distance threshold dynamically. It relies on the counter information from the Network layer and the signal strength information from the physical layer and shows the adaptive behavior. It drastically reduces the effect of the mobility and no exchanged messages or control messages are needed. Adaptive distance-counter threshold is to provide both a satisfied coverage, less broadcast and average latency.

The rest of this paper is organized as follows. Section 2 presents some definitions and symbols. Section 3 gives the system model. Section 4 describes Adaptive distance-counter threshold broadcast algorithm (ADCT). Section 5 evaluates the proposed scheme and shows the simulations results. And the conclusions are drawn in section 6.

2 Formal Definitions and Symbols

An ad hoc network can be mapped to a unit disk graph $G(t)=(V,E)$, where V is the set of nodes and E is the set of logical edges at which two nodes are connected if their geographical distance is within a given transmission range r. Considering the effect of the mobile nodes, $G(t)$ is a time-relevant function.

The symbols and definitions used in this paper are defined as follows:

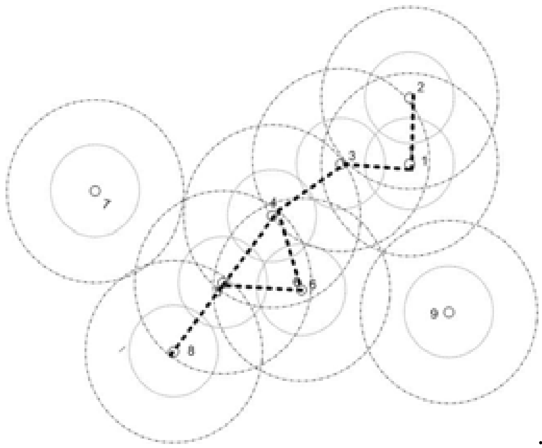

Figure 1: An ad hoc network

Definition 1: $d(u,v)$ is defined the distance between node u and v within their transmission range r. $d(u,v) \le r$.

Definition 2: $c(u)$ denotes the number of received messages in node u during broadcasting.

Definition 4: D_{Th} denotes a distance threshold, which is calculated by using d and constant α

$D_{Th} = \alpha$ d where $0 \le D_{Th} < r$.

Definition 5: D_{pth} denotes the previous calculated distance threshold

Definition 6: C_{Th} denotes a counter threshold, where $C_{Th} \ge 0$.

Definition 7: $N(u)$ is a set of neighbors of node u, $v \in N(u), d(u,v) \le r$. See Figure1 the neighbors of node 1 consist of node 2, 3 represented as $N(1) = \{2,3\}$ or the neighbors of node 5 consist of node 4, 6, 8 represented as $N(5) = \{4,6,8\}$

Definition 8: $I(u)$ is a subset of $N(u)$, $v \in I(u), d(u,v) \le D_{DTh} \le D_{Th}$ .In Figure 1, $I(1) = \Phi$.

Definition 9: $E(u)$ is a subset of $N(u)$, . $v \in E(u), (D_{DTh} < d(u,v) \le r) \cup (D_{Th} < d(u,v) \le r)$

See Figure 1, $E(1) = \{2,3\}$.

Definition 10: $Rt(u)$ is a set of nodes that retransmit the message from source node,

$$Rt(u) = \left\{ u \mid u \in \left\{ \begin{array}{l} \{E(u_1) \cap E(u_2) \cap \cdots E(u_k)\} \cup \\ \{u \notin \{E(u_1) \cap E(u_2) \cap \cdots E(u_k)\}, c(u) < C_{TH}\} \end{array} \right\}, u_i \in V \right\}$$

The following assumptions are made in our system model. Mobile nodes in an ad hoc network share a single common channel, and a message transmitted by a node reaches all its neighbors at the same time. The maximum transmitting radius of each node in the network is the same. There are no unidirectional links.

The broadcast messages do not require an explicit acknowledgement to confirm the reception. We are getting number of counts c from the Network Layer and the distance d between two nodes From the Physical Layer.

3 Proposed System Model

It is true that the creation of standalone protocols, without keeping in mind the higher or lower layers, has facilitated vastly development to designer. However many questions and practical details expand along several layers, mainly in wireless systems. In this section a conceptual cross-layer model is presented for Ad hoc layers.

3.1 Cross Layer Model

The conceptual cross-layer diagram can be observed in Figure 2. The model is based on the division of network features in two main groups.

Physical layer with its key parameters- such as transmit power, modulation, coding rate, antenna beam coefficients has a direct impact on multiple access of nodes in wireless channels through affecting the interference at receivers and susceptibility to it. Local adaptation of these parameters to achieve a target BER restraint broadcasting decisions by altering the directed topology graph, feasible transmission schedules, and payload transmission rates. Physical layer features such as transceiver complexity, power required to drive the RF modules, and the transmitted power determines the transmission decision of node at the network layer.

Network layer plays an important role in topology control. In general, a broadcast algorithm is a Network Layer algorithm. Network Layer determines that how many times a node has broadcasted. So it helps in decreasing the number of rebroadcasts. It is responsible for scheduling the transmissions and allocating the wireless channels. Network Layer transfers data across the physical connection between two systems. As a result of transmission schedules, number of rebroadcasts, high packet delays and/or low bandwidth can occur, forcing the routing layer to change its route decisions.

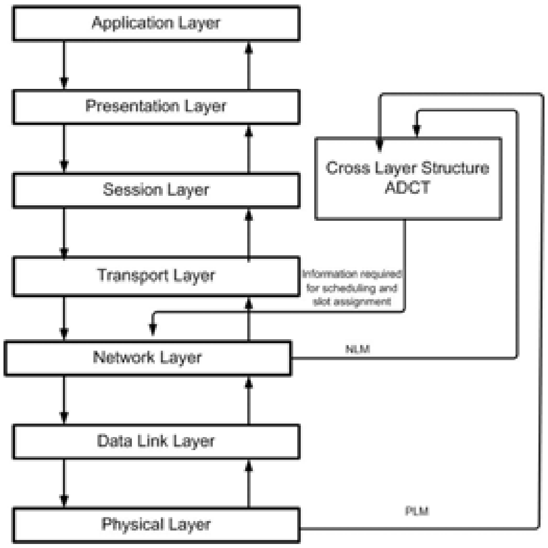

Figure 2: Cross Layer Structure

From [13], we can get

$$P_r = P_t A G_t G_r d^{-n} \qquad (1)$$

$$d = \sqrt[n]{A\frac{P_r}{P_t G_t G_r}} \qquad (2)$$

where P_r is receiving power, P_t is transmitted power, A is the propagation constants, G_t is the transmitted antenna gain, G_r is the receiving antenna gain, n is the path loss, d is the distance between source and destination calculated by signal strength.

In ADCT, we use the parameters from physical layer and network layer. From physical layer, we use transmit power and received signal strength to calculate the distance between source and destination. From network layer, we use the number that how many times a node has received the same broadcast message from other nodes. Information required for scheduling the transmitting determined by ADCT is as follow,

$$T^i_{delay} = \frac{f(c(i))}{d(i,x)}$$
$$f(c(i)) = \begin{cases} 1, i \in \{E(u_1) \cap E(u_2) \cap \cdots E(u_k), u_i \in V\} \\ c(i), i \in \{\overline{E(u_1) \cap E(u_2) \cap \cdots E(u_k)}, c_{x_j} < C_{Th}, u_i \in V\} \end{cases} \qquad (3)$$

In (3), T^i_{delay} denotes the delay time in network layer of node *i*.

4 ADCT Algorithm

In this section, an efficient distributed heuristic-based algorithm is presented. The proposed algorithm aimed at solving the broadcast storm problem without consuming additional network resources, such as bandwidth and energy. This algorithm works on the basis of information of Cross Layer Structure.

4.1 Algorithm

Our approach to alleviate Broadcast storm problem is to intelligently inhibit some hosts from rebroadcast to reduce redundancy, contention, collision and to get better coverage, better throughput and less delay. In order to alleviate the broadcast storm problem, $Rt(u)$ has to be found by an efficient distributed heuristic-based algorithm. The relationship between the redundancy of a broadcast and the additional coverage is revealed in [11].

Moreover, it also shows the relationship among the additional coverage, $d(u,v)$ and $c(u)$ i.e. the farther $d(u,v)$ is, the larger additional coverage of a node can be acquired, and the larger $c(u)$ is, the smaller additional coverage of a node can be acquired. [14] Tries to get the large additional coverage and avoid the worst saved broadcast and more latency time at the same time. But in some situations it can’t get the required results. We have proposed an intelligent algorithm which also works in these situations.

Each broadcast packet has an additional field of distance in its header. Whenever a node transmits a broadcast packet, this field has the information of distance between the transmitting node and the source from which it received transmission.

The algorithm works as follows. When a node *u* sends a broadcast message, its neighbors will receive *message* and compute $d(u,v)$ according to the signal strength from equation (2). Let x is the neighbor node of v and hears message from v, It’ll calculate the distance threshold from d(u,v)., $D_{th} = \alpha$ d, where 0.7< α <0.8.(The distance threshold would be calculated by every node would be compared from the previous calculated distance threshold. we’ll take the distance threshold which would be larger). Now x will compute its distance from v and compare with the calculated distance threshold. If the d_n is less than D_{th} then

If $x \in \{E(u_1) \cap E(u_2) \cap \cdots E(u)\}$ or

$x \notin \{E(u_1) \cap E(u_2) \cap \cdots E(u)\}, c(u) < C_{Th}$, $\{u_1, u_2, \cdots u\} \subseteq N(x)$, it is easy to get that $x \in Rt(u)$ and node x waits for a short time. The delay helps to avoid nodes transmitting message all at once. If node v didn't receive any messages during this short delay, it will transmit message when time expires. Otherwise, it will compute the distance from the sending node and wait again. If $c(v) \geq C_{Th}$, node v stops transmitting.

The algorithm can be described as follows:

1. Initialize D_{pth}= 0, C_{Th} = C (C =1,2…6)

2. If a message "msg" is heard by a node other than the source node, then calculate the distance "d" between that node and the source node

3. Use the function given in section 4.1 to calculate the $D_{th.}$

4. Compare the D_{th} with its distance d_n from its neighbors to decide whether it is in the range D_{th} or not. If d_n<D_{th}. Proceed to C1. Else go to F1.

C1 Initialize the counter c=1 when the broadcast message is heard for the first time. In F1 if the message is heard again, interrupt waiting and go to C2, else go to F1.

C2 c=c+1. If c<Cth resume the interrupted waiting in F1. Else go to F2.

F1 Wait for the short time determined by distance-counter function. If the message is heard again during waiting then if the node is in DTM (Distance Threshold Mode), go to 2, else go to C2. Else submit for transmission and wait until transmission actually starts. The message is on air. Exit.

F2 Cancel the transmission of msg if it was submitted in F1. The host is inhibited from rebroadcasting message. Exit.

In JDCT if the source node is surrounded by nodes such that the distance of each node from the source node is less than Distance threshold then all the surrounding neighbor nods will depend on the counter threshold for further retransmission and will face the shortcomings(coverage problem) of counter threshold based scheme. Our Algorithm overcomes this problem by calculating the distance threshold dynamically from the cross layer information.

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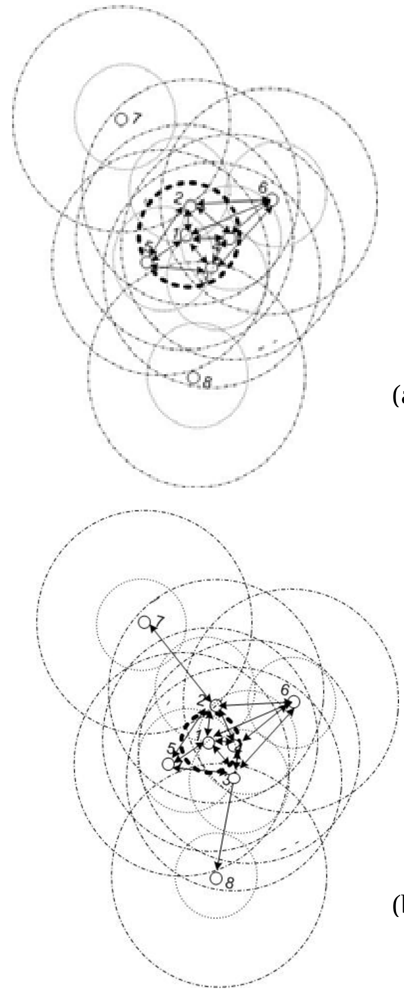

(a)

(b)

Figure 3: Comparison for redundant to broadcast among (a) JDCT algorithm (b) ADCT algorithm

As in Figure 3 we can see that dynamic distance threshold provides a better reachable than JDCT because there is no fixed distance threshold. In some situations ADCT has the same performance but in some situation it has better Performance than JDCT because it is using more reliable information. We have proved this better performance by simulation results.

The comparison with the JDCT and ADCT will be given through an example in Figure 3. First some assumptions are given as follows.

1. The sequence of retransmission is decided by its distance to the source node. The larger the distance is, the earlier the node may transmit. From the Figure. 3 we can see 6 is the source node and the sequence of retransmission from the source node is 6-1-2-3-4 because d (6,1)> d(6,2)> d(6,3)> d(6,4). By this example we shall show that JDCT Algorithm cannot cover

the nodes 7 and 8 but ADCT can cover these nodes.

2. We assume that C_{th}=3
3. D_{th} is dynamic and it will be calculated at the run time
4. Now from the aforementioned definition

$$N(1)=E(1)=\{2,3,4,5,6\}, I(1)=\Phi\cdot$$
$$N(2)=E(2)=\{1,2,3,4,5,6,7\}, I(2)=\Phi\cdot$$
$$N(3)=E(3)=\{1,2,3,4,5,6,8\}, I(3)=\Phi\cdot$$
$$N(4)=E(4)=\{1,2,3,4,5,6\}, I(4)=\Phi\cdot$$
$$N(5)=E(5)=\{1,2,3,4\}, I(4)=\Phi$$
$$N(6)=E(6)=\{1,2,3,4\}, I(6)=\Phi$$
$$N(7)=E(7)=\{2\}, I(7)=\Phi$$
$$N(8)=E(8)=\{3\}, I(8)=\Phi$$

We don't know about the threshold of any node before the transmission starts. After the transmission start every node will calculate threshold in distribute manners.

So we assume that in the start I= Φ and E=N.

In Figure 3a each node uses the JDCT algorithm to decide whether to retransmit or not. The result matches the analysis in [12].

In Figure 3b each node uses the ADCT algorithm to decide whether to retransmit or not. The nodes decide as follows,

Step 1: Node 6 is the source node that starts transmission which is received by neighbor nodes 1,2,3,4.

Step 2: Node 1 is the furthest node among the neighbor nodes of the node 6, so node 1 retransmits M first.

Step 3: As $N(1)=E(1)=\{2,3,4,5,6\}, I(1)=\Phi$, so when node 1 retransmits first of all node 5 will hear node first and calculate D_{th} according to algorithm. So according to algorithm $N(1)=\{2,3,4,5,6\}, E(1)=\{2,3,5\}, I(1)=\{4\}, c(4)=1$, for d(1,5)> d(1,3)> d(1,2), node 5 will retransmit the msg in the next step.

Step 4: When node 5 retransmits the message, all its neighbors (node 2, 3, 4) will received the message and calculate D_{th} again. And we can get $N(5)=\{1,2,3,4,6\}, E(5)=\{1,2,3,4,6\}, I(5)=\Phi, c(4)=2$ and as d(5, 2)> d(5, 3), node 2 will retransmit the message in the next step.

Step 5: When node 2 retransmits the message, we can get $N(2)=\{1,3,4,5,6,7\}, E(2)=\{3,4,5,6,7\}, I(2)=\Phi, c(4)=3>C_{Th}$ as $c(4)=3>C_{Th}$, node 4 is saved and node 7 is covered by node 2.

Step 6: When time expires, node 3 will retransmit the message and node 8 will be covered.

5 Simulation Results

Simulations are performed to evaluate the new broadcasting algorithm and compare with other existing algorithms. A Mobility Framework for OMNeT++ [15] is used as a tool. The network possesses 100 nodes in a 1000×1000 meter square. Nodes in the simulation move according to "random waypoint" model. The transmitting radius of each node is 230 meters and channel capacity is 10Kbits/sec. The mobility speed of a node is set from 0 m/s to 30 m/s. The CSMA/CA is used as the MAC layer in our experiments. Three distributed broadcasting algorithms are compared, as following.

– SB**:** straightforward broadcasting algorithm
– JDCT**:** JDCT broadcasting algorithm
– ADCT**:** **A**daptive DCT broadcasting algorithm

The performance measures of interest are:

- Average latency: defined as the interval between its arrival and the moment when either all nodes have received it or no node can rebroadcast it further.
- Ratio of Saved Rebroadcast (RSR): the total number of saved rebroadcast nodes is divided by the total number of nodes receiving the broadcast message

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- Reachability: the number of nodes that receive broadcast packets divided by the total number of nodes

In order to compare the performance of the algorithm, we use parameters in our algorithm as same as in [12] That is, $D_{Th}=0.9r, C_{Th}=3$. The first set of experimental results Figure 4 demonstrates the coverage of different algorithms. Notice that SB cannot guarantee 100% coverage because of the existing hidden/exposed terminals. As we use a dynamic threshold scheme, ADCT can get a higher coverage than JDCT does.

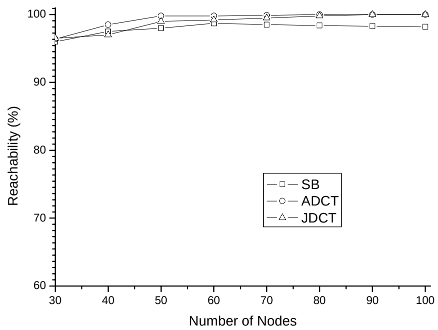

Figure 4: Reachability of different Algorithms

The average latency using different broadcast algorithms with varying node speeds is reported in Figure 5. Figure 6 shows the ratio of saved rebroadcast using different algorithms with varying node speeds (from 0 to 30m/sec).

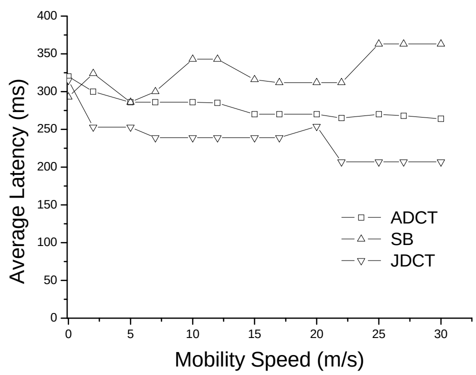

Figure 5: Average Latency vs. Mobility speed

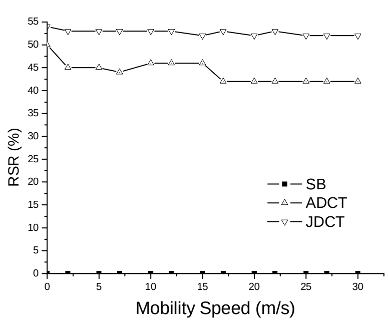

Figure 6:.RSR vs. Mobility speed

In ADCT, because more nodes are selected to retransmitting than those in JDCT, the average latency and the ratio of saved rebroadcast of ADCT are higher than JDCT but lower than SB.

6 Conclusion

This paper presents a cross layer based efficient distributed broadcasting algorithm in ad hoc Networks. The algorithm is adaptive in nature and relies on cross layer information. The accuracy of algorithm has been shown by simulation results. It runs in a distributed manner by each node without needing any global information. ADCT gets a higher broadcast coverage than JDCT at the cost of adding a little protocol overhead. The simulation experiments have demonstrated the efficiency of proposed broadcast algorithm. It's suitable for mobile ad hoc networks.

7 References

[1] Li Layuan, Li Chunlin: Genetic Algorithm-Based QoS Multicast Routing for Uncertainty in Network Parameters. Proc. of 5th Asia-Pacific Web Conference, APWeb 2003, Xian, China, Appril 23-25, 2003, Proceedings, 430-441

[2] Li Layuan, Li Chunlin: A routing protocol for dynamic and large computer networks with clustering topology. Computer Communications, Vol. 23(2), Elsevier, UK (2000) 171-176

[3] David B. Johnson, David A. Maltz, Yih-Chun Hu, and Jorjeta G. Jetcheva: The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR). http: //www.ietf.org/internet-drafts/draft-ietf-manet-dsr-09.txt, April 2003

[4] Li Layuan, Li Chunlin: Acta Informatica. A distributed QoS-aware multicast routing protocol. Computer Science, Vol. 40 (3). Springer-Verlag GmbH (2003) 221-233

[5] J. Cartigny, D. Simplot: Border Node Retransmission Based Probabilistic Broadcast Protocols in Ad-Hoc Networks. In Proc. 36th International Hawaii International Conference on System Sciences (HICSS'03), Hawaii, USA. 2003

[6] Li Layuan, Li Chunlin: A QoS multicast routing protocol for dynamic group topology. Information Sciences, Vol. 169(1-2). Elsevier, UK (2005) 113-130

[7] C. E. Perkins, E. M. Royer: Ad hoc on-demand distance vector (AODV) routing. In Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, Feb. 1999

[8] S. Ramanathan, M. Streenstrup: A Survey of Routing Techniques for Mobile Communication Networks. Mobile Networks and Applications, pp. 89-104, 1996

[9] E. Royer and C-K. Toh: A Review of Current Routing Protocols for Ad-Hoc Mobile Wireless Networks. IEEE Personal Communications, Vol. 6(4). IEEE Communications Society (1999) 46-55

[10] J. Broch et al: A performance comparison of multi-hop wireless ad hoc network routing protocols. Proc. ACM MOBICOM, ACM Press New York (1998) 85-97

[11] Y.-C. Tseng, S.-Y. Ni, Y.-S. Chen and J.-P. Sheu: The Broadcast Storm Problem in a Mobile Ad Hoc Network. MOBICOM'99, ACM Press New York (1999) 151-152

[12] Sun Qiang, Li Layuan: An Efficient Distributed Broadcasting Algorithm for Ad Hoc Networks. APPT 2005,LNCS 3756 page no 363-372

[13] Kaveh Pahlavan, Prashant Krishnamurthy. Principles Wireless Networks: A Unified Approach. Prentice Hall, 2002: 46-57.

[14] A. Qayyum, L. Viennot, A.Laouiti: Multipoint relaying for flooding broadcast messages in mobile wireless networks. In Proceedings of the 35th Annual Hawaii International Conference on System Sciences (HICSS’02), Hawaii, 2002

[15] A. Vargas: OMNET++Discrete Event Simulation System. version 3.0 edition, 2005