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Analytical Event Based Investigations Over Delphi Random Generator Distributions for Data Dissemination Routing Protocols in Highly Dense Wireless Sensor Network

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Abstract This paper focuses on the event based investigations over different data dissemination routing protocols for highly dense wireless sensor networks. Initially for the wireless sensor network domain, we analyzed data dissemination flooding and gossiping routing protocols. We etude and exemplify our proposed model for data dissemination based evaluation with Delphi random generator distribution strategy. We calculated performance metrics as sense count, transmit count, receive count and receive redundant count. At the end, simulations analysis has been carried out to prove the validity of our designed scenario.

Keywords Flooding · Gossiping · Events · Sense count · Transmit count · Receive redundant count

1 Introduction

Recent advancement towards the minimization of microelectronics and mechanistic structures (MSME) led to battery based sensor nodes with intellection, infusion and processing capabilities [1, 2]. Wireless sensor networks innovated a new domain of application areas such as military navigation, artificial structural and weather monitoring system and target tracking system [3, 4]. Wireless sensor network constitutes a large number of tiny nodes deployed in ad-hoc fashion in order to accomplish a distributed sensing task by

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automatically configuring topology for communication and coordination with each other [5].

Other application areas of wireless sensor networks include remote monitoring [6, 7], feature capturing [8], joint line monitoring, inventory tracking, wild fire and health monitoring. Energy efficiency acts as an extremely important criterion in the performance determination of entire wireless sensor networks system. Wireless sensor nodes are battery operated which always remains typically a scarce and expensive resource. Hence, focus on energy efficient communication techniques remains indispensable for the enhancement of network life time in the wireless sensor network. In broadcasting communication technique, one node sends the packets to all the other nodes in the network. Many applications such as location identification, routes establishment and related queries use broadcasting or its variation. Broadcasting can be useful for finding the multiple path discoveries between nodes and route maintenance. One of the variations of broadcasting where each node retransmit packets when received for the first time. Resultant of flooding generates redundant transmission which leads to broadcast storm problem [9]. Minimizing the broadcasting overhead remains always on the top priority for the protocol designer for wireless sensor networks. In the literature, a number of proposals were given by different research groups. Centralized broadcasting approaches were presented in references [10–12]. To reduce redundant messages using neighborhood information in wireless ad-hoc networks, solution were proposed in references [13–18]. Efficient data dissemination remains the highest priority for the assessment of routing protocol in the wireless sensor network system. An optimal route surely enhances the performance of the overall system, but it may not be shortest. Packets delivered in duplicate to the destination result in more resources utilization and consume higher energy. Specifically in the case of bulky and disruptive environment, the track keeping on entire message becomes extremely difficult. Network size influences the performance of the entire operating environment when evaluating a specific routing protocol. The motto remains there to carefully investigate routing protocols and present an optimal resultant that can comply with the expected requirement without compromising any constraints. Therefore, a typical analysis should be required to access the scope of different data dissemination routing protocols for the wireless sensor networks.

Section 2 deals with surveys two data dissemination routing protocols for wireless sensor networks. Section 3 describes the meticulous design of our evolved scenario. Simulation consequences and some open problems are presented and discussed in Sect. 4. Finally, Sect. 5 concludes this paper followed by the references.

2 Data Dissemination Protocols with Related Prior Work

This section provides the background and related work on flooding and gossiping protocols with assumptions required for the designed framework for the later sections.

2.1 Data Dissemination Flooding Protocol

In this protocol, each node receives a packet broadcast up to maximum hop count threshold value provided it does not act as the packet destination. This methodology does not prescribe complex constraints like topology maintenance and route discovery in the network. Every node receives a packet and retransmits the same packet after caching the source identity and sequence number of the message to all of its neighbors and may results in propagation of various unnecessary routing messages. Three major loop holes with flooding protocol namely—implosion, overlap and resource blindness were identified by Heinzelman et al. [19]. A straightforward broadcast of packets become costly in terms of time and energy with the CSMA an implementation mechanism. Ni et al. [20] reported the seriousness of this broadcast storm problem consequences in redundancy, contention and collisions. Proposals for reducing the broadcast problem were reported by researchers in Ref. [20, 21]. Lot of energy gets wasted in contention and collision as proposals remain CSMA based. TDMA based MAC protocol INFUSE for data dissemination was proposed in Ref. [22]. It reduced energy and time taken for flooding but also considers implicit acknowledgment for lossy channels which result in extra energy consumption. Recently time synchronization through flooding has been bestowed due attention. Elson et al. [23] eliminated transmitter side non determinism. A hierarchical level structure was proposed in Ref. [24] where the root node initiates the control phase and the control messages relays from higher level to lower level nodes resulting in synchronization error reduction. Both the schemes reported in Ref. [23, 24] for large message exchange inherits synchronization error which results in data loss. Flooding time synchronization as a solution uses inherent broadcast property to synchronize several receivers as showed in Ref. [25]. Zeng et al. [26] invented a synchronization scheme based on TDMA to reduce energy consumption and proposes guidelines for size determination of synchronization frame. There can be wastage of time if the size of the frame remains too large or too small and also makes the calculation and reception computation complex. Shanti and Sahoo [27] investigated TDMA based protocol TREEFP where after topology information gathering, slots have been assigned without message passing and proved higher reliability as compared to Ref. [26]. As per the TREEFP requirement, each node should be aware about its position relative to the sink either by some localization algorithm or with nodes programming during the deployment time.

2.2 Data Dissemination Gossiping Protocol

A modified version of the flooding protocol refers to gossiping protocol, where the nodes send the packets to randomly selected neighbor but do not broadcast packets. As a resultant it avoids the problem of implosion, but on the other side a message takes more time to propagate throughout the network. Gossiping considerably lowers the flooding protocol overhead but does not guarantee about the message delivery to all nodes across the network. To eventually propagate the message gossiping protocol relies on the randomly selected neighbor. Recent researches suggested the significance of gossip protocols towards the engineering a new generation of monitoring systems incorporating criteria such as high scalability and fault tolerant [28]. Till date, however, no monitoring systems based on gossiping have been developed. Wuhib et al. [29] presented research work on gossip-based aggregation for real-time monitoring [30] and evaluated gossip-based monitoring against traditional tree-based monitoring. Gossip protocols also known as epidemic protocols, are actually based on round specific distributed algorithms. Each node selects a subset of other nodes to interact with in a round, whereby the selection function remains probabilistic. Nodes interact via “small” messages as reported in [28, 31, 32]. Initially Gossip protocols were proposed for the purpose of disseminating updates in large database systems [31]. More recently the scope of these protocols have enhanced for various other tasks such as robust overlays construction [33], network slicing [34], network size estimation [35] and network wide aggregates monitoring [30, 32]. In terms of Gossip bimodal behavior [36–40], Let p be the gossip probability and for sufficiently large graphs with fractions $\theta^S(p)$ and $\theta^R(p)$ arranged in such a manner the gossip quickly dies out in $1 - \theta^S(p)$ of the executions Almost in all of the fraction $\theta^S(p)$ of the executions, a fraction $\theta^R(p)$ of the nodes get the message if the gossip does not die out otherwise in many cases, $\theta^R(p)$ remains close to 1.In case of pure gossip, a source sends the route request with probability 1 and when a node first receives a route request with probability *p,* it broadcasts the request with probability $1 - p$ *to its neighbors provided* it discards request; if the same request again received by the node. Initial condition shows the problem of very few neighbors. For the first k hops, we gossip with probability 1 and for $k + 1$ hops, the gossip probability is p. GOSSIP1 (1, 1) shows equivalent behavior to the flooding. GOSSIP1(p,1) represent equivalent behavior to pure GOSSIP1(p). if $\theta_0^S(p)$ denotes well-defined probability and $\theta_0^F(p)$ = Message reception probability and forwardness then following relation holds for gossip protocol $\theta_0^S(p) = \theta_0^F(p) =_{\text{def}} \theta_0(p)$ provided $\theta_0^S(p) < 1$. We used gossip algorithm as an extension of the standard nearest-neighbor gossip reported by Boyd et al. [41] using mobility model in natural manner. In a graph G, each time agents move independently to new locations with random selection. For each time $t = 1, 2\ldots$ the following events occurred. Let i and j denotes agents, $l_i(t)$ denotes new location, μ_i denotes mobility distribution, $\mathcal{N}li(t)$ denotes a set, then following relation holds:

$$\mathcal{N}li(t) = \{k \in v : (li(t), lk(t)) \in \varepsilon.\} \tag{1}$$

$$x_k(t) = \begin{cases} \frac{1}{2}\left(x_i(t-1) + x_j(t-1)\right) & k = i.j \\ x_k(t-1) & k \neq i,j \end{cases} \quad agent\ i,j\ exchange,\ update\ values \tag{2}$$

True average with probability greater than $1 - \varepsilon$ represented by following relation

$$T_{ave}(n, \in) = \sup_{x(0)} \inf_{t=0,1,2,\ldots} \left\{ \mathbb{P}\frac{\| x(t) - x\bar{1}^{\rightarrow} \|}{\| x(0) \|} \geq \in \right\} \leq \in \tag{3}$$

where $\|\cdot\|$ denotes the Euclidean norm. Denantes et al. [42] analyzed that bounds on the spectral gap yield an asymptotic deterministic rate of vanishing error. Authors in [43] analyzed bounds in a way that can be used to correlate both the rate of convergence in probability and averaging error which decays in exponential and asymptotic manner.

3 Proposed Evaluation Model

In this section, we present the investigation framework for data dissemination based on parameters namely—sense count, transmit count and receive redundant count in the highly dense wireless sensor networks. For this, we have developed a whole scenario focusing on three main targets. First, we are concerned with finding the number of node operations of our proposed framework. In other words, we want to find out the summation of operations in the entire model. Since our model has a strong basis on node operation counting, we considered that it would be also quite interesting to take care about the number of events in terms of specific protocols for the proposed model. Smaller number of node operation is always given due consideration as it consumes fewer resources. Finally, as a possible measure of the adaptability of our model, we made the inclusive evaluation of two data dissemination protocols in our proposed framework scenario. Table 1 displays the parameters in our proposal.

The simulations had the following structure. We launched our model with 10 numbers of events (i.e. each event request for a service 10 times with respect to number of nodes) over 500–2500 wireless sensor networks randomly generated with Delphi random generator distributions. The sensor field constitutes width and height 2000 m with an individual range of node and sensor 200 m. In the simulation model, value of sectoral sweeper coefficient and lobe count value remain 2 with beam angle 90 with counter clockwise direction of operation in the proposal. Figure 1 shows the set up of our simulation.

4 Results and Discussions

To evaluate the performance of our approach, we used an event driven wireless sensor network simulator SNetSim [44, 45] over Windows platform. It allows the researchers to simulate and represent random network distributions and provides statistics of different data dissemination policies including the provision for high density node environment. The proposed model was verified on two data dissemination protocols and we reported a comparative analysis over classical flooding and gossiping protocols. In the simulation, we collected data for three metrics namely sense count, transmit count and receive redundant count. Sense count metric exhibits the capability of a wireless sensor node to measure number of signals required for sensing operation whereas transmit count metric shows the number of signals required during transmission for a specified number of nodes present in the scenario. Receive redundant count metric reflects the number of fraudulent signals occurred during the overall communication.

Figure 2 indicates the comparative analysis of flooding and gossiping protocols based on events. Initially, we calculated sense count (SC), transmit count (TC) and receive redundant count (RRC) for 500 nodes. In case of flooding protocols, sense count operation shows incremental behavior as compare to gossiping protocol which consumes less sense count operations. As far as transmit count operation concerns, flooding protocol exhibits zigzag behavior but the gossiping protocol shows continuous growth with respect to the increment of the number of events. For receive redundant count operation, gossip protocol

Table 1 Scenario parameters

Scenario options	Value
Sensor field Width (m)	2000
Sensor field Height (m)	2000
Nodes	500–2500
Range RF (m)	200
Number of events	10
Event range (m)	200
Data dissemination protocols	Classical flooding, gossiping
Distributions	Delphi random generator
Sectoral sweeper coefficient	2
Lobe count	4
Beam angle (°)	90
Beam direction	Counter-clockwise

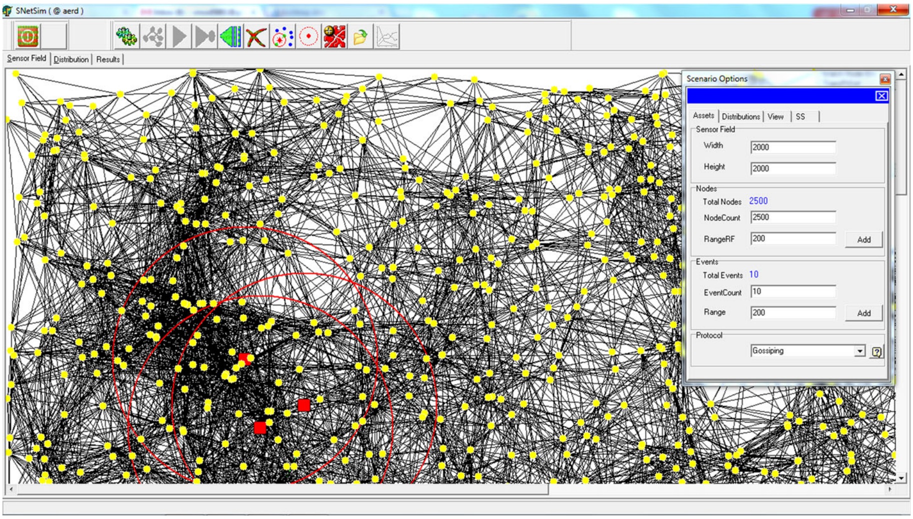

Fig. 1 Simulation setup

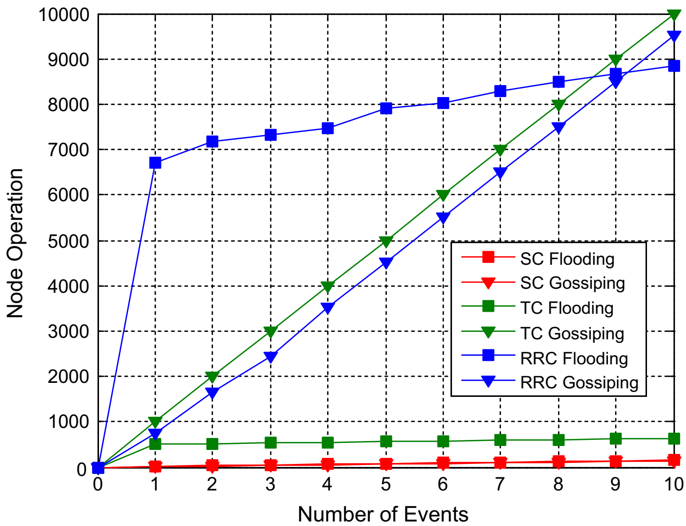

Fig. 2 Event based comparison of flooding versus gossiping protocol with 500 nodes

outperforms than flooding protocols. This shows the good agreement with the results reported in Ref. [46]. A typical comparative investigation over broadcast protocol for sensor network and ad-hoc broadcast protocol for 100 nodes networks was reported by Arjan et al. [46]. We enhanced the contribution to a certain extent by incorporating highly dense wireless sensor networks where the node value ranges from 500 to 2500.

Figure 3 reflects approximately similar behavior provided the comparison lies for 1000 nodes resulting in more number of operations in the scenario with respect to the number of events. Node scalability affects all the three metrics operations.

Sense count operation in flooding protocol changes its value to more than three times, when compared with gossiping protocol. In case of transmit count, number of operations from the first event to the last event varies from 999 to 1709 in flooding protocol whereas the value enhanced ten times in case of gossiping i.e. from 2000 to 20,000. The SC flooding has high value of node operation in case of receive redundant count for flooding still i.e. 89,406–153,316 whereas for gossiping it lies in between 1256 and 19,002 operations. Moving ahead towards further comparative evaluation, an analysis of flooding and gossiping protocol for 1500 and 2000 nodes is illustrated in the Figs. 4 and 5. The operations for sense count metrics remains less than flooding in gossiping protocol at the first event and exceed than flooding protocol for the last events for both the cases of 1500 and 2000 nodes. In flooding protocol number of operation for transmit count decreases with increase in the number of events with respect to scalability. More number of nodes, lesser will mean the difference corresponds to operations value. On the other hand, gossiping shows precipitous increase in its value of operations corresponds to the events value increment. With the increase in number of nodes, the value to receive redundant count metric increases in case of flooding protocol and decreases for gossiping protocol.

Finally, we evaluated our proposed model for highly dense wireless sensor network with 2500 nodes as showed in Fig. 6. Each node requests for a service correspond to each event and sequence continues for all the nodes residing in the network. Sense count metric requires more number of operations in flooding protocol than gossiping protocol. Transmit count operations vary in a steadfast manner in gossiping protocol than flooding protocol. There remains very superior number of receive redundant count operations in flooding protocol than gossiping protocol. This reflects that gossiping protocol is more robust than flooding protocol even in the highly dense wireless sensor networks.

Arjan et al. [46] reported only the performance evaluation of broadcast protocol for wireless sensor network and ad-hoc broadcast protocol with 100 numbers of nodes. We

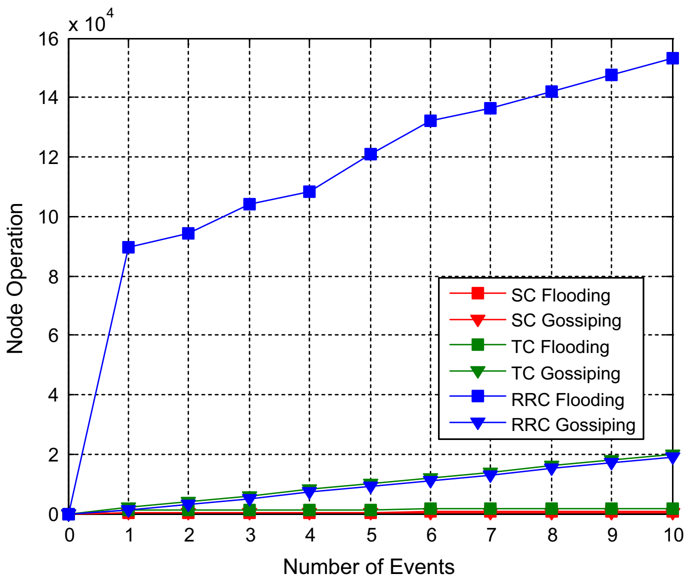

Fig. 3 Event based comparison of flooding versus gossiping protocol with 1000 nodes

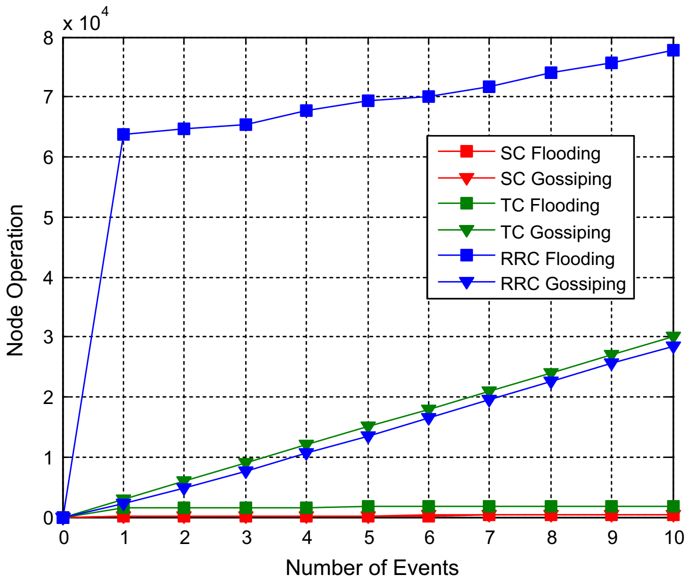

Fig. 4 Event based comparison of flooding versus gossiping protocol with 1500 nodes

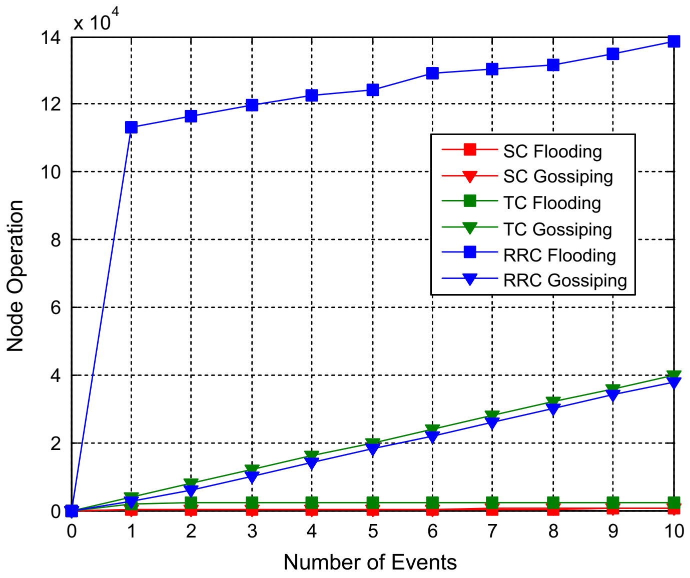

Fig. 5 Event based comparison of flooding versus gossiping protocol with 2000 nodes

have extended the concept towards more scalability and robustness. Harshavardhan et al. [46] explored classical flooding, modified flooding and location aided flooding up to 1000 nodes. We extended this concept of Ref. [47] for flooding and gossiping protocol. Verma et al. [48] presented scalability analysis of AODV routing protocol in wireless sensor

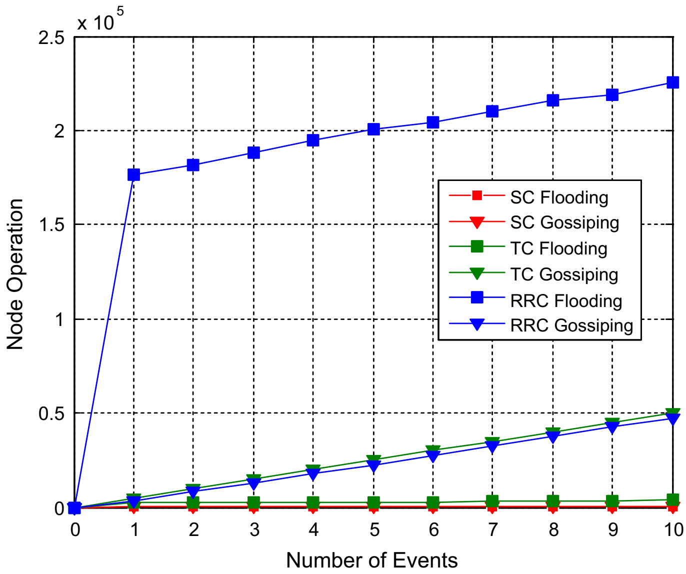

Fig. 6 Event based comparison of flooding versus gossiping protocol with 2500 nodes

networks. Here we further enhanced the concept towards more rigorous analysis of highly dense wireless sensor networks. Our analysis shows that gossiping protocols consumes less number of resources and more efficient as compared to flooding protocol with respect to the number of events. The summarized evaluation of node operation for flooding and gossiping protocols confirming our arguments stated as below in Table 2.

5 Conclusion and Future Work

Wireless sensor networks have proved to be a novel and innovative research field of work in the last few years. We have evaluated a highly dense WSN framework which implements two data dissemination routing protocols with respect to performance metrics: sense count, transmit count and receive redundant count. We estimated flooding and gossiping protocol specifically for node operations with reference to the number of events. The goodness of the routing protocols changes along with the number of nodes and event present in the scenario. Here, first time works focused toward the comparative analysis of highly dense WSN routing protocols. We reported preliminary simulation demonstration our proposed scenario. Our research on wireless sensor network assessment continues along specified directions. The current state of art in these models, a number of aspects like sense count, transmit count, and receive redundant count have been identified and analyzed. We investigated towards the implementation and assessment of these models in our proposed scenario. The resultants show that gossiping protocol performance overweighs flooding protocols in highly dense wireless sensor networks in all the cases node count operation from an efficiency viewpoint. Future work can be focused on three major aspects viz enhancement, restructuring and extending the experiments carried out to demonstrate

Table 2 Overall experimental summarization

	Node of operation										
Number of events→	1	2	3	4	5	6	7	8	9	10	11
500 nodes											
Flooding protocol	SC	20	42	55	66	87	99	115	132	144	156
	TC	499	521	534	545	566	578	594	611	623	635
	RRC	6701	7185	7338	7463	7895	8026	8276	8508	8682	8848
Gossiping protocol	SC	11	22	33	46	62	82	94	110	127	137
	TC	1000	2000	3000	4000	5000	6000	7000	8000	9000	10,000
	RRC	737	1660	2445	3523	4521	5504	6503	7503	8503	9503
1000 nodes											
Flooding protocol	SC	110	170	271	324	439	555	612	688	750	820
	TC	999	1059	1160	1213	1328	1444	1501	1577	1639	1709
	RRC	89,406	94,243	104,239	108,121	120,818	132,115	136,318	142,148	147,385	153,316
Gossiping protocol	SC	32	70	83	104	125	161	189	213	232	263
	TC	2000	4000	6000	8000	10,000	12,000	14,000	16,000	18,000	20,000
	RRC	1256	3210	5056	7029	9020	11,015	13,015	15,003	17,002	19,002
1500 nodes											
Flooding protocol	SC	45	69	95	145	186	208	249	295	336	383
	TC	1499	1523	1549	1599	1640	1662	1703	1749	1790	1837
	RRC	63,824	64,571	65,357	67,713	69,471	70,146	71,755	73,923	75,621	77,801
Gossiping protocol	SC	23	62	111	166	213	262	301	345	384	415
	TC	3000	6000	9000	12,000	15,000	18,000	21,000	24,000	27,000	30,000
	RRC	2106	4772	7634	10,544	13,512	16,506	19,504	22,503	25,502	28,501

Table 2 continued

	Node of operation										
Number of events→	1	2	3	4	5	6	7	8	9	10	11
2000 nodes											
Flooding protocol	SC	70	124	184	234	272	346	378	408	461	525
	TC	1999	2053	2113	2163	2201	2275	2307	2337	2390	2454
	RRC	113,210	116,314	119798	122,469	124049	128,988	130,466	131,642	134,687	138,373
Gossiping protocol	SC	62	114	172	229	304	357	415	493	553	611
	TC	4000	8000	12,000	16,000	20000	24,000	28000	32,000	36,000	40,000
	RRC	2667	6136	10,071	14,038	18,017	22,010	26,005	30,004	34,003	38,003
2500 nodes											
Flooding protocol	SC	66	138	218	306	377	438	515	593	637	721
	TC	2499	2571	2651	2739	2810	2871	2948	3026	3070	3154
	RRC	176,566	181,874	197,926	195,021	200,371	204,235	209,979	216,215	218,869	225,178
Gossiping protocol	SC	60	129	212	288	364	422	506	567	610	655
	TC	5000	10,000	15,000	20000	25,000	30000	35,000	40,000	45,000	50,000
	RRC	3563	8053	12,881	17,718	22,633	27,544	32,522	37,519	42,506	47,505

accuracy of our proposed model. Finally, we expect this work seems to a benchmark for designer for enhanced evaluation.

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