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A Comparison Study for Service Replication Protocols in MANETs

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Abstract

Mobile ad hoc networks (MANETs) are characterized by high dynamics in particular with respect to the formation of network partitions. Typically, one aim of MANETs is to allow for the sharing of functionality and information among the participant nodes. A paradigm that allows for functionality sharing is service orientation where functionality provided by one node is offered as a service to other nodes. The presence of unconnected partitions makes the deployed services inaccessible to some network participants. Service replication is employed as an approach to overcome this problem and to ensure higher service availability and accessibility although the partitioning behavior. In the literature, several protocols and algorithms for service replication in MANETs have been proposed. This report identifies different criteria suitable to compare these approaches. In particular, we focus on comparing the Service Distribution Protocol (SDP), proposed in our previous work, to existing approaches. After a high-level comparison of a number of approaches, an in-depth case study that compares SDP to one representative existing approach is presented. Results show that SDP is promising and its performance comparable to traditional.

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I. Introduction

The challenging features of MANETs, especially the partitioning behavior, decrease the availability of network resources for their participants. Since sharing resources and capabilities in a collaborative manner is vital in such networks, in such ensuring higher availability of resources is very important as well. Service orientation can provide a solution for supporting MANETs' collaborative activities. Resources of the network can be represented as services. These services can be offered to the other network participants. However, to ensure high service availability and accessibility, measures need to be taken to counteract the effects of network partitioning. Service replication across multiple nodes can help to increase service availability. In general, replication can ensure higher resource availability and is being applied in many systems and applications such as distributed databases and storage systems. Unfortunately, none of these replication schemes can be applied directly to MANETs. Since ad hoc networks consist of an ever changing set of distinct partitions, replication protocols need to take this into account. In contrast to more classical settings, partitioning is more the rule than the exception in these networks and should thus not hinder protocol performance significantly.

Over the last few years, replication protocols and algorithms have been developed to overcome the challenges of MANETs. Since the partitioning behavior is the main actor that affects service availability, most of these protocols focus on obtaining a complete image of the current network status and try to predict the network partitioning behavior.

In general, all of these protocols and algorithms share a main feature: they query the lower network layer, e.g., the routing components, to obtain information. Besides being expensive and time consuming, these querying processes make the proposed protocols and algorithms architecture-dependent.

The service distribution protocol (SDP) [1], [2], [3], [4], [5], [6] has been proposed to overcome this disadvantage of the other protocols. Its main contribution is to base the replication decision only on information from the application layer. It uses information that indicates the service popularity and does not need to predict the partitioning behavior. Based on the importance of a specific service, which is time varying, SDP's replication decision is computed shared among the service provider and its clients. Moreover, when a service becomes unimportant for clients, it will be hibernated (shut down). SDP is advantageous compared to other protocols because of its architecture independence. One other important advantage of SDP is achieved through the automatically varying importance degree of a service which means that not all services will be replicated each time when a network partition is found, but only the interesting services. [3] contains more discussions about SDP and its advantages.

This report discusses the various concepts behind service replication in MANETs and how the existing protocols and algorithms achieve these concepts. Moreover, a detailed comparison among these protocols is shown. Finally, a case study that contains a detailed simulation to reflect the differences between the performance of one representative of these approaches [7] as based on predicting network partitioning and SDP is presented.

The structure of the report is as follows: In Section II, a set of related protocols and algorithms are presented. Basic concepts and criteria of these presented protocols and algorithms are introduced and discussed in Section III. A detailed comparison among the presented protocols and algorithms is given in Section IV, followed by a case study that compares results of simulation on SDP to the protocol performance of [7] in Section V. Finally, conclusions are stated in Section VI.

II. Service Replication Protocols and algorithms for MANETs

In this section we introduce a set of notable service replication protocols for MANETs. A brief description for each is presented.

Hauspie et al. [8] present a replication decision algorithm based on link evaluation. It assumes presence of a suitable routing protocol that can be queried for long links in dense MANETs. The authors assume that not only the network partitioning behavior is the main actor in the process of service replication but also the long wireless links, links with several intermediate nodes, which affect the quality of the delivered functionalities. The algorithm detects these long wireless links and tries to deploy a replica at the closest valid node to the clients by employing a set of concepts like robustness of paths and service path quality.

Karen et al. [9] introduce a partition prediction service coverage algorithm for MANETs. Once a partitioning behavior has been detected, it tries to push a replica in the farthest node in the departing partition. In case of presence of two or more servers in the same network partition the server with the eldest ID is allowed to continue. Using the relative speed, a client should search for reliable providers in terms of similar relative speeds. The authors assume the existence of group mobility patterns in the network and use these patterns to predict the network partitioning. A set of algorithms to perform the velocity analysis is proposed. Moreover, presence of a suitable routing protocol is assumed.

Zheng et al. [10] provide a dynamic, adaptive replica allocation algorithm which aims at minimizing the communication cost of the replication process. It combines the two concepts of topological change analysis and frequency of requests (read/write requests) to perform its replication processes. It allocates the produced replicas where it can minimize its access cost. It suggests the usage of a GPS or suitable routing protocol for processes of the topological change analysis. It assumes that the replica nodes (providers) can exchange a write request (transactions) immediately once they receive any transaction that changes the replica's state.

Dustdar et al. [11] introduce a web service replication protocol for mobile services. It depends also on an analysis for topological changes and selects the best node for hosting a new replica. Each client should find a primary copy of the service for its requests based on the available resource. It assumes that background lazy updates for the concurrent replicas will be sufficient. An internal database to keep track of the global status of the network is required. The protocol suggests service hibernation based on monitoring and analysis of the network status.

Derhab et al. [7] propose a protocol for service replication over MANETs based on a partition prediction algorithm [12] which employs the TORA routing [13] protocol. A replica is placed on the partition predicting node and produces an intermediate passive server. If there are no servers in the new predicted partition, the passive server becomes an active server. If there is more than one active server in a network partition, a merging algorithm will be triggered. Mobile clients are supposed to communicate only with the active servers.

Jin et al. [14] introduce a set of replication strategies for data contents and services in multi-hop wireless mesh networks. It reveals the structure of the optimal replication strategy to minimize object access cost and communication overhead. We do not consider directly this set of strategies in our related work because wireless mesh networks always have a certain fixed structure and topologies.

The service distribution protocol, SDP, is being based on the interest information only which can be provided simply from the application layer. This SDP feature enables it to be architecture independent. Unlike the other approaches, SDP needs no network status analysis or partition predication techniques. A replica is hosted by clients once they show enough interest (in terms of requesting frequency). SDP provides two server election modes [6], short and long election mode, to be used during the leader election processes, i.e., to determine whether and where to host or hibernate a replica. Mobile clients should find the best replica, in case of multiple concurrent running replicas, to direct their requests for. During service discovery processes and by using a suitable service ranking criteria, a common index can attribute a set of equivalent replicas. The best replica or service is selected based on this common index. Replicas which get more interest will be replicated more, others will be hibernated. SDP assumes by using a suitable caching scheme and the mobility of the mobile nodes, an interesting service will prevail through the network. SDP management of the concurrent replicas is still ongoing.

III. Basic Concepts and Criteria

In this section, a list of criteria that can describe the service replication process is proposed. We will use these criteria to compare the proposed approaches. Criteria will be identified along a set of questions: Under which events will a new replica be created? Where will a new replica be placed? How are concurrent replicas being managed? What type of replication is being used?

A. Replication Decision

The replication decision refers to what triggers the replication process. It has two dimensions: time and location. In this research, the term ”replicator component” refers to the component that is responsible for the replication process. It does not matter whether it is located on the provider or client side.

1) Time: Producing replicas is controlled by a set of events that reflects the current status of the environment. At the occurrence of some events (individually, mutually or concurrently) the replicator component decides to produce a (set of) replica(s) to maintain higher service availability. In MANETs, the partitioning behavior is a popular candidate to be used as an indicator for necessity of the replication process. Based on the prediction of newly forming partition, the replicator component tries to push a replica inside it before the partitioning process finishes. Other approaches, as in [8], especially for dense MANETs, try to keep the number of hops to reach the service as small as possible. Therefore the replicator components are supposed to spread replicas to the far parts of the network to keep the quality for accessing their services higher. Also, service popularity has been introduced as an indicator to be taken into consideration during the replication process.

2) Location: The replica placement processes complement the replication process. It allocates the new produced replica to a new place in the network. The replica placement process is based mainly on the motives of the replication process. Partitioning behavior of MANETs, avoiding long paths to a service, and the service interest affect the replica placement process. Regarding the natures of MANETs, the efficient service replication process of services in such networks requires continuous replication decisions to ensure higher service availability. The process of placing a new replica on a mobile node (replica allocation process) should be complemented by another process, which deallocates no longer needed replicas. In this way, the replica distribution can be adapted in the network and preserves its resources.

B. Selection

Selection of one mobile node (leader) from a set of alternatives to be responsible to deliver a specific functionality inside its partition is a common issue in MANETs. The selection of a leader is known as the ”leader election” problem [15], [6]. Leader election is very important for managing a set of concurrently running replicas in a given situation. Leader election can be achieved based on some criteria like mobile node stability [16], available resources [11], locations or network routing and topology features like [17].

On the other hand, from a client perspective, a service invocation can be understood as a selection process as well, in which mobile clients are selecting one out of a set of reachable providers. The following questions can describe generally the role of the service invocation in the selection: How can a client find a service provider? What should it do when it looses its provider? Can a client continue from a specific point of execution when switching between two providers? If the service can be cached, when is it allowed for a client to restore it from its cache and publish it for the other network participants?.

C. Management of Concurrent Replicas

Client requests to a service can be either read, write, commit, or abort requests (transaction). Transactions term comes from the field of database and concurrency control. It indicates the whole required operations to be done to meet (respond) a service request on the provider side. Some of theses transactions can change the status of a service or one of its replicas. If the service consistency needs to be ensured, not only how to maintain a specific service consistent against a set different transactions should be taken into consideration, but also how to manage the required updates between the whole set of concurrently running replicas.

Keep in mind that it will not be always possible to preserve a set of replicas inside a MANET consistent. Regarding the partitioning behavior, two network partitions may remain separated forever each with its own replica which operates under different sequences of transactions. In this case, while replicas are in separate partitions, no recovery mechanism can be applied to keep these replicas consistent. How are update messages exchanged between the different replicas? How can the state of a service be synchronized to stand consistently with different client requests? The previously mentioned questions are very important to be answered by any replication approach for services in MANETs.

D. Taxonomy

Service replication in ad hoc environments can be regarded as a special case of replication in P2P environments. [18] introduces a survey on Peer-to-Peer (P2P) replication systems and introduces a set of important criteria and features that can systematize the presented protocols and algorithms in this study. In fact all of these protocols assume that all of the network participants have the same resources and peers. MANETs can be considered as P2P environments with tighter constraints. The used taxonomy in this work can conclude the type and behavior of the stated replication approach.

- Single master vs. multi-master: This criterion determines the relation between replicas inside the network. A primary copy accepts read and write operations, while the secondary copy accepts only read operations. A single master replication approach allows only one primary copy for each replicated service. A multi-master replication approach allows many primary copies for the replicated service.
- Full replication vs. partial replication: This criterion reflects the targeted locations to be hosting the produced replicas. While full replication denotes that the service is to be replicated over all available nodes in the network, partial replication refers that the replicas will be partially hosted on some of the mobile nodes.
- Synchronous vs. asynchronous: Regarding service transactions, synchronous service replication approaches assume service/replicas to be synchronized (against the different applied transactions). On the other hand, asynchronous service replication approaches does not require (some of/all) service/replicas to be synchronized at least for sometime.
- Optimistic vs. pessimistic: Optimistic replication approaches expect that conflict between concurrently running replicas will be very rare, while the pessimistic approaches expect the opposite and implement more conflict-aggressive mechanisms to keep the concurrent replicas synchronized.
- Pull-based vs. push-based: In pull-based replication approaches, clients are supposed to ask their own replicas from a server. In contrast, push-based replication approaches let servers dominate the whole replication process.

IV. Comparisons

The protocols, which have been previously mentioned in Section II and SDP, have been compared to each other against the criteria which have been discussed in Section III. As shown in Table I, this comparison show a detailed description about these protocols. As a result of these comparisons, the protocol described in [7] has been chosen to be compared in terms of performance to SDP. Derhab (2007) [7] (PSRP) shows a complete set of solutions, regarding the criteria of table I, for service replication in ad hoc network. It provides a typical well described partitioning bevaior detection process based on a TORA routing component. Although Dustdar et al. [11] also show a complete consideration for these criteria, but it is only concerns one type of services, namely web services, and assumes presence of the required infrastructure for that. Moreover, [11] describes the presence of the network analysis component but it does not discuss how it operates. Both Karen et al.[9] and Zheng et al. [10] show a push based replication approach which requires more computational effort from the hosting node (server). Hauspie et al.[8] introduce algorithm which is designed for MANETs but it considers replication to avoid long links (with many intermediate hops) in very dense networks where there is no possibility of network partitioning behavior. The following case study highlights and discusses a set performance comparison criteria between SDP and PSRP through using a detailed simulation.

Protocol		HAUSPIE et. al(2002) [8]	Karen et. al (2002) [9]	Zheng et. al(2004) [10]	Dustadr et. al (2007) [11]	Derhab et. al (2007) [7]	SDP(2008) [1], [2], [3], [6], [5]
Replication Decision	When?	On long (Bad) connections to a server in terms of quality are detected.	On partition predicted	On higher read-write and topological changes	On topology of network status changes	On partition predicted	On highh Interest detected by a client
	Where?	A closer node to the client.	Most far distance node in a departuring group of nodes	Neighbor nodes where the decrease in the access cost is greater than the increase of the update cost	Best suitable node in terms of its available resources	Nodes which predicted the partitionoing behavior	Interesting node
Selection?	Leader (S)election? (Multi-Server Perspective)	-	An elder-ID selection is carried out	Replicas with requests from replica-nodes higer than the gained request of the common nodes should be relinquished	Most resourced node is elected	Stable active server	Short election mode Long election mode
	Provider Selection? (Invocation Perspective)	Nearst servers are selected	Clients select a reliable service in terms of stable connectivity with similar velocity	-	Primary copy of a replica	Available active server	Most Interesting in terms of requirements
Management of concurrent replicas		-	-	Simply via replica nodes as write requests	background lazy updates	Force multiple replicas to be merged if there are more than one active server in a partition	
Techniqes		Robustness of paths	Predicting the partitioning behavior based on group mobility patterns	Stable neighbor Service access request	Internal Database Monitor Hibernation	Partition Prediction Residual link lifetime	Hibernation Caching Gross Interest
Requires?		Suitable routing protocol	Caching Analysis for velocities of the mobile nodes Suitable routing protocol	A GPS is suggest or a suitable routing component to evaluate the neighborhood satability History Information for vinicities	Caching Requires a global view for the whole network status	TORA [13]	
Taxonomy		Pull-based Asynchro. Partial Optimistic	Push-based Asynchro. Partial Optimistic	Push-based Asynchro. Partial Non-optimistic	Pull-based Asynchro. Partial Non-optimistic	Pull-based Asynchro. Partial Non-optimistic	Pull-based Asynchro. Partial Optimistic
Performance Metrics		No. of disjoined paths No. of emitted packets	Service Coverage Service Cost	Communication cost Access cost Update cost	Network traffic and scalability Response time	Service availability Service cost Prediction error	Success ratio Service availability Service prevalence Replication degree Allocation Correctness
Comments	Adv.	Dense network	Realistic group mobility patterns		Web Services Statful services	Low cost High Availablity	Architecture independent
	Disadv.	Network Resources statful services	Network Resources statful services	Costly Requires time to reach a steady state	Costly	Prediction error with higher velocities of nodes Caching	Stateful services Requires longer time for a steady state

TABLE I
COMPARISON ON DIFFERENT SERVICE REPLICATION PROTOCOLS AND THEIR CRITERIA

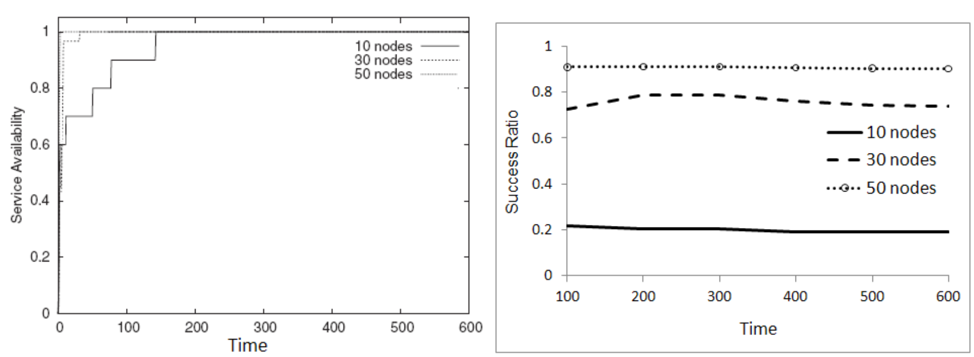

Fig. 1. Service Availability of PSRP (left hand side) and Success Ratio of SDP (right hand side)

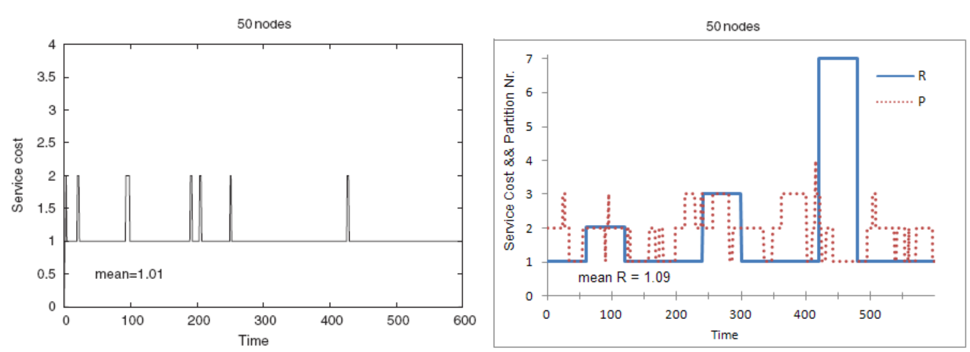

Fig. 2. Examples on Service Cost for PSRP (left hand side) and SDP (right hand side)

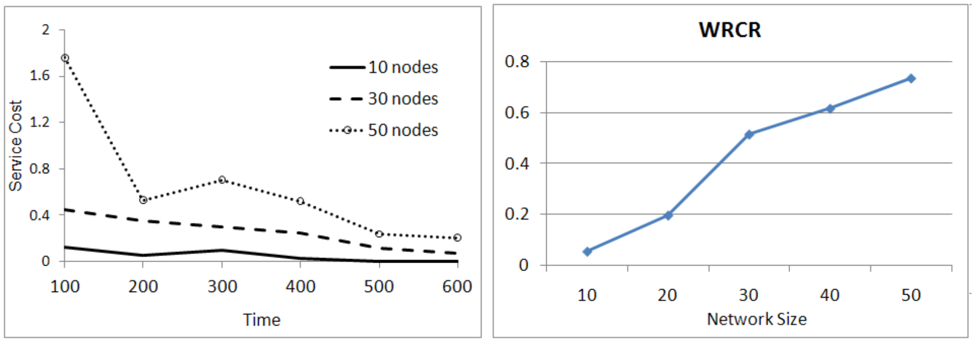

Fig. 3. Average Service Cost for SDP (left hand side) and its WRCR (right hand side)

V. Case Study

In this study, a detailed comparison between two service replication approaches namely SDP and PSRP is presented. SDP has potential differences from the other discussed protocols and algorithms in this work. PSRP represents a typical traditional partition prediction based service replication protocol for MANETs. PSRP introduced a complete partition detection algorithm based on link evaluation features with help of a well described routing algorithm (TORA). Regardless the issue of quality, PSRP assumes, as SDP, that one active service or replica inside a network partition can satisfy all of these partition participants.

In [7], a simulation study for PSRP is introduced. Its performance analysis is based on three criteria: service availability, service cost, and prediction error. In this study, we are more interested in the first two parameters, since SDP does not depend on any prediction, so the error prediction parameter would not be interesting criteria to be included through this study. The used parameters in this case study are as follows:

- Service Availability: The ratio between the number of nodes that can access the service to the network size (total number of nodes).
- Service Cost: The average number of generated active and passive (replicas on the partition predicting nodes) per the network partition
- Success Ratio: Average ratio of the number of succeeded calls of the whole mobile hosts in the network to the total number of calls.
- Weighted Rational Allocation Correctness Ratio (WRCR) [3]: ratio between 0 and 1 that indicates the correctness of the overall replica allocation process in the whole network at a certain time. It is computed as follows:

$$WRCR = \Sigma_{i=0}^{n} \left(\frac{Pz_i}{size(Net)} . RCR(P_i) \right) \quad (1)$$

where (Pz_i) is the partition size of a given i_{th} partition and (RCR) is the Rational Allocation Correctness Ratio in a given network partition (P_i):

$$RCR(P_i) = \begin{cases} 0 & R_i = 0 \\ 1 & R_i in \{1,2\} \\ \frac{3}{R_i} . \frac{Pz_i - R_i}{Pz_i - 2} & R_i > 2, P_i > 2 \end{cases} \quad (2)$$

where (R_i) is the number of active replicas in the i_{th} partition.

RCR represents an inverse proportional relation between the size of a network partition to the number of active replicas inside it. The higher number of active replicas, the lower RCR. It assumes that only one active replica inside a partition is the optimum service distribution so it gives 1 in this case. Because SDP is a replication approach and assumes that at least a replication process should proactively take place once, SDP does not penalize the case of presence of two active replicas inside a partition and considers this also as an optimum distribution. For all other cases, RCR decreases as number of active replicas increases on rational basis. $WRCR$ accumulates all $RCRs$ overall network partitions relatively to the weight of its partition to the whole network size. [3] shows more details about WRCR and discusses other different proposed computation methods to highlight the correctness of the replica allocation process.

In order to compare SDP to PSRP, the following facts need to be taken into consideration.

1) For SDP, it is important to have a request model. This is the main influence in the replication/hibernation processes. It determines the generated requests and how the clients produce them regarding the service content. [3] introduces and discusses a proposed requesting (calling) model and how the produced gross interest can be quantified. In this work, we are going to use a ”Poor” gross interest which is proposed in [3]. The poor gross interest quantifies a very low number of calls (requests) in each network partition with a long period of pause periods. We also use a high number of different client groups namely four. These groups differ in their maximum calling rate which ranges between 0 and 3 calls per minutes. The replication threshold, i.e., the minimum calling rate a client must reach in order to be allowed to obrtain

a replica is set to three calls/minute. Together with the different client groups, this results in only one quarter of the clients in a partition being eligible for a replica. More details about client groups and their affects on SDP performance are presented in [3], [5].

2) Since SDP introduces a different perspective for the concept of replication and lends it to be just based on the service interest or popularity, it allows more than one active replicas inside a partition. On the other hand PSRP is aiming to keep just one active server per partition in despite of errors in the partition detection process which may produce unwanted replicas. Generally, SDP assumes 1 to 2 replicas in a given partition is optimum situation [3].
3) PSRP assumes that, as the other previously mentioned protocols, that all of the deployed services are important to be replicated once they detected motive changes in the network status. They do not take into consideration if these services are important to be replicated in the new partitions. SDP has a different concept of replication. It replicates only the popular services and by such concept it reduce the required effort of the whole service content. This replication concept affects the meaning of replication, instead of this; SDP uses another performance criteria which is service success ratio. Success ratio indicates the ratio between the number of succeeded request (to reach a service/replica) to the total number of generated requests by the clients in all network partitions. From SDP perspective, not all of mobile nodes are interested in the service, for that SDP uses success ratio to indicate the service availability for just these interested nodes.
4) In this study, a short election mode [6] for the concurrent replicas is used by SDP, in which provider hibernates (if the replica is already cached) its replica, if they do not receive at least one call in the minimum time interval which is allowed for the provider to get at least one call. [6] suggests that time interval to be one second. Otherwise the hibernation minimum time interval is one minute.

[7] suggests a random way point mobility model for the mobile nodes [19], in which each node selects uniformly and randomly a destination in a $1000m \times 1000m$ square area with no obstacles and a speed between 0 and a certain maximum speed V_{max} (10 m/s), then it stays during a pause time of 1 s before selecting a new random destination and a speed and so on. Each mobile node can cover a 198 m radio transmission range about itself. One node is selected to host the original service in the beginning of the simulation. The simulation time is set to be 600s.

For this study, we have applied the network settings used in [7] for our own simulations of SDP. Our showed results are coming out of 20 times runs. We directly use the results of PSRP presented in [7] to compare our results to, i.e., we have not reimplemented PSRP, but rely on the evaluation results presented in [7] for our comparison. More work about verification of the PSRP evaluation results is ongoing in our research group.

In Figure 1 we compare PSRP's service availability with SDP's success ratio. These measures are similar. The only difference is, that service availability measures the possibility to obtain the service for any node in the network, while the success ratio looks only at nodes that are actually interested in the service, i.e. it is based on successful service calls. The figure shows, on the left hand side, that PSRP can achieve higher service availability even in networks with a low node density (10 nodes) as time is incremented. SDP's success ratio is depicted on the right hand side of Figure 1. Since it depends on the mobility of nodes and requires more time to evaluate the calls' periods, the success ratio is negatively affected by the network density. In a very sparse network, the service will be propagated very slowly only to all nodes, as it takes some time for new connections to be formed. As the network density increases from 10 to 30 and 50 nodes, the average success ratio increases from 0.20 to 0.75 and 0.91 respectively. Regarding the concepts of replication shown by SDP, the low network density produces a very low gross interest which cannot maintain the service or any of its replicas alive [3], [5]. This very low gross interest indicates that the service is not popular at this scale of network density. For example, if we assumed that all of the mobile nodes are belonging to the same network partition (and that of course is not a feasible assumption based on the previous network settings) and taking into consideration applying the poor gross interest scenario [3], the expected number of nodes asking to host a replica will be about 0.5.

Figure 2 shows on the left hand side a snapshot for one run from the behavior of PSRP's service cost at network density of 50 nodes as presented in [7]. It shows how the replication starts once a network partitioning behavior is detected and how it is deallocated (two or more replicas are merged once it is sensed that they are in the same network partition). On the right hand side, the replication process (number of active replicas R - service cost) of SDP is dominated not only by the number of formed partitions (P) but also by the popularity of the service at certain time. This explains why the R curve does not obey the P curve.

Actually, in our opinion, the kind of curve depicted in Figure 2 does not show an important result to be taken into consideration as a performance attribute, but serves just as an example on how these protocols (PSRP and SDP) are acting. What is really missing in [7] as well as in [9] which goes on in the same fashion and contains a sample presentation for the proposed algorithm that shows a sample behavior at only one simulation run, is how to quantify both service cost and correctness of the replica placement (allocation) process as an average over all runs. WRCR can be used as such a measurement as we are going to show in the next paragraphs.

Figure 3 shows, on the left hand side, the resultant average service cost per network partition. It shows how this cost converges to a low level for all network densities. The important question here is how is the efficiency of this convergence, i.e., is it reached at the price of decreasing allocation correctness? On the right hand side of Figure 3, the $WRCR$ ratio is depicted. [3] introduces a set of different allocation correctness computation methods and highlights WRCR as the best for different reasons. This ratio is a good indication for the correctness of the replica allocation process. The figure shows that SDP can achieve a replica allocation process with a high $WRCR$ replica allocation process. $WRCR$ increases as the network density increases and this is normal however the generated gross interest by higher number of clients is expected. SDP can achieve about 0.62 in average with 0.17 standard deviation of WRCR starting between 30 and 50 nodes. $WRCR$ reaches about 0.73 average with 0.19 standard deviation.

VI. Conclusions

In this report, we have identified a number of criteria to compare different service replication methods in ad-hoc networks among them the factors that influence the replication and replica placement decisions, the way concurrent replicas are managed and the replication type. We have used these criteria to classify a number of replication approaches and have idenified PSRP as a suitable candidate for an more in depth comparison to our own protocol, SDP. PSRP is suitable for this comparison, because on the one hand it is somewhat typical for a whole class or replication approaches and on the other hand the underlying network model is similar enough to ours to allow for a meaningful comparison of simulation results. We have described this comparison in detail in this report. It shows on the one hand, that SDP can compete with other approaches, but on the other hand, also makes obvious, that more detailed, common simulation runs will be needed for a detailed analysis. This is what we are currently working on.

References

[1] Mohamed Hamdy and Birgitta König-Ries. A service distribution protocol for mobile ad hoc networks. In *proceedings of the International Conference on Pervasive Services (ICPS 08)*, Sorrento, Italy, 2008.

[2] Mohamed Hamdy and Birgitta König-Ries. An extended analysis of an interest-based service distribution protocol for mobile ad hoc networks. In *proceedings of the International Conference on Wireless Information Networks and Systems (WINSYS 2008)*, Porto, Portugal, 2008.

[3] Mohamed Hamdy and Birgitta König-Ries. Service availability, success ratio, prevalence, replica allocation correctness, replication degree, and effects of different replication/hibernation behavior effects of the service distribution protocol for mobile ad hoc networks -a detailed study-. Technical report, 01.12.2008 Math/Inf/08/08, Institute of Computer Science, Friedrich-Schiller-University Jena, 2008.

[4] Mohamed Hamdy and Birgitta König-Ries. *E-business and Telecommunications Revised Selected Papers of International Conference on E-business and Telecommunications (ICETE 2008)*, chapter The Service Distribution Protocol for MANETs -Criteria and Performance Analysis-. Communications in Computer and Information Science. Springer, To appear, 2009.

[5] Mohamed Hamdy and Birgitta König-Ries. Effects of different hibernation behaviors on the service distribution protocol for mobile networks and its replica placement process. In *International Workshop on the Role of Services, Ontologies, and Context in Mobile Environments (RoSOC-M '09) in conjunction with the 10th International Conference on Mobile Data Management (MDM'09)*, Taipei, Taiwan, May 2009.

[6] Mohamed Hamdy and Birgitta König-Ries. Leader election modes of the service distribution protocol for mobile ad hoc networks. In *proceedings of the fourth German Community Conference on Mobility and Mobile Information Systems (4. Konferenz Mobilitt und mobile Informationssysteme) (MMS 2009)*, Mnster, Germany, March 2009.

[7] Abdelouahid Derhab and Nadjib Badache. A pull-based service replication protocol in mobile ad hoc networks. *European Transactions on Telecommunications*, 18:1–11, 2007.

[8] Michael Hauspie, David Simplot, and Jean Carle. Replication decision algorithm based on link evaluation for services in manet. Technical report, University of Lille, France, 2001.

[9] K. Wang and B. Li. Efficient and guaranteed service coverage in partitionable mobile ad-hoc networks. In *Proceedings of the IEEE Computer and Communications Societies Twenty-First Annual Joint Conference (INFOCOM 2002)*, New York, USA, 2002.

[10] Zheng Jing, Su Jinshu, Yang Kan, and Wang Yijie. *Stable Neighbor Based Adaptive Replica Allocation in Mobile Ad Hoc Networks*, chapter Computational Science - ICCS 2004, pages 373–380. Lecture Notes in Computer Science. Springer Berlin - Heidelberg, 2004.

[11] Schahram Dustdar and Lukasz Juszczyk. Dynamic replication and synchronization of web services for high availability in mobile ad-hoc networks. *Service Oriented Computing and Applications*, 1:19–33, March 2007.

[12] Abdelouahid Derhab, Nadjib Badache, and Abdelmadjid Bouabdallah. A partition prediction algorithm for service replication in mobile ad hoc networks. In *proceedings of the Second Annual Conference on Wireless On-demand Network Systems and Services (WONS 2005)*, Swi, 2005.

[13] Park, Corson. Internet-Draft: Temporally-Ordered Routing Algorithm (TORA) - Functional Specification. http://tools.ietf.org/html/draft-ietf-manet-tora-spec-02, 1999.

[14] Shudong Jin and Limin Wang. Content and service replication strategies in multi-hop wireless mesh networks. In *proceedings of the 8th ACM international symposium on Modeling, analysis and simulation of wireless and mobile systems (MSWiM '05)*, pages 79–86, New York, NY, USA, 2005. ACM.

[15] Abdelouahid Derhab and Nadjib Badache. A self-stabilizing leader election algorithm in highly dynamic ad hoc mobile networks. *IEEE Transactions on Parallel Distributed Systems*, 19(7):926–939, 2008.

[16] Orhan Dagdeviren and Kayhan Erciyes. A hierarchical leader election protocol for mobile ad hoc networks. In *proceedings of the 8th International Conference on Computational Science (ICCS 2008)*, pages 509–518, Kraków, Poland, 2008.

[17] N. Malpani, J. L. Welch, and N. Vaidya. Leader election algorithms for mobile ad hoc network. In *Proceedings of the 4th international workshop on Discrete algorithms and methods for mobile computing and communications*, pages 96–103, 2000.

[18] Vidal Martins, Esther Pacitti, and Patrik Valduriez. Survey on data replication in p2p systems. Technical report, INRIA, Rennes, France, 2006.

[19] Christian Bettstetter, Hannes Hartenstein, and Xavier Pérez-Costa. Stochastic properties of the random waypoint mobility model. *Wirel. Netw.*, 10(5):555–567, 2004.