Exploiting Movement synchronization to Increase End-to-end file Sharing efficiency for Delay Sensitive Streams in Vehicular P2P Devices

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***Abstract*—A significant aspect of wireless systems is the intermittent-connectivity experienced by nodes, where sudden network partitioning problems rarely allow a connected path between a source node and its destination. Replication of any requested object and redundancy face the requests' failures whereas they create severe duplications and aggravate the capacity of the end-to-end path. This work quantifies the parameters that affect the end-to-end efficient transmission by taking into consideration the synchronization between moving peers in order to assign the requested resources in the end-to-end path. Synchronization and assignment of the moving Mobile Infostation (MI) peer to a certain vehicle is done with the introduced Message Ferry (MF) mobile Peer in a unidirectional way. A resource assignment cooperation engine is being developed with respect to the cooperation model and end-to-end capacity using passive message ferries in order to efficiently enable delay sensitive streaming. Simulation results have shown that the scheme offers high throughput and reliability and a robust solution for sharing resources of any capacity in dynamically changing mobile peer-to-peer wireless environments.**

Keywords-synchronized mobility scheme; partially synchronized mobility scheme; file sharing scheme; end-to-end efficienc; evaluation through simulation.

I. INTRODUCTION

The development of new applications on-the-move, demands the exploration of new dynamically adjusting approaches that enable reliability in an end-to-end manner. Many constraints exist in such networks like resource availability whereas the topological scheme followed in these infrastructures should be combined with the availability of the requested resources and the time-access for sharing resources of each device with the synchronized motion within a specified time duration t as in real time Vehicle-to-Vehicle (V2V) communication, in a cooperative manner. A Vehicular Ad-Hoc Network (VANET) is a technology that uses moving cars as devices/nodes in a dynamically changing network to establish a mobile network connectivity. In this paper a reliable file sharing scheme for vehicular Mobile Peer-to-Peer (MP2P) devices is proposed taking the advantages of moving devices within a specified roadmap with different pathways like in real time vehicular networks. This work exploits the movements of the devices and the passive device synchronization to increase end-to-end file sharing efficiency through vehicular users and mobile Infostations [1]. Through geographical roadmaps landscapes where mobile Infostations are set and initialized, the passive synchronization enables through the replication policy to create a replicated object in order to enable reliable file sharing. Role-based Mobile Infostations (MIs) are selected based on their velocity, residual energy, remaining capacity etc and are assigned according to the passive Message Ferry peer. This scheme proved its scalability in node's density since it does not require the knowledge of network at any single host. Additionally it does not require spatial distributions to efficiently spread information while enables reliability in supported mobility without the scheduled 'rendezvous', whereas it effectively passes the requested replicas to designated users.

The organization of the paper is as follows: Section II discusses the related work that has been done on similar schemes which use similar approaches for establishing and maintaining end-to-end file sharing efficiency. Section III then introduces the proposed model on the wireless mobility with the exploitation of passive movement synchronization to increase end-to-end file sharing reliability and a stochastic measure to estimate the end-to-end capacity within the path where the requested replicas were created. Section IV shows the experimental performance evaluation of the proposed scheme and the comparisons done under different convergent parameterized conditions. Particular focus was paid on the impact of certain movements made by Vehicular-Peer-to-Peer (VP2P) devices where multi-client applications dynamically demand resources directly from certain nodal vehicles. For this consideration a stochastic model is introduced for the end-to-end capacity measurements and the dynamic caching activity of the requested objects onto opportunistic neighboring devices.

II. RECENT SCHEMES AND WORK DONE

Mobility in autonomic communication is an essential parameter and along with the user's demands they pose the vision of what self-behaving flexibility should encompass in next-generation self-tuning behavior [1]. The capacity of the nodes which are traversed in the requested path, can be reduced significantly particularly if we are dealing with delay sensitive traffic or bursty traffic [1] whereas the underlying end-to-end supporting mechanism should be aware of the dynamic movements in a Peer-to-Peer manner. Obviously, if the transmission-range of a node increases, then the interference it causes will increase and probably the number of nodes which will have copy/copies of the packets that should be forwarded, will increase. Toumpis and Goldsmith [2] define and study capacity regions for wireless ad hoc networks with an arbitrary number of nodes and topology. These regions describe the set of achievable rate combinations between all source-destination pairs in the network under various transmission strategies for EC content sharing and power control. In this work we consider the capacity but in an end-to-end path-request manner and take into consideration the variations caused by the dynamic movements of the devices/vehicles. Most existing architectures (including Grace [3], Widens [4], MobileMan [5]) rely on local information and local devices' views, without considering the global networking context or views which may be very useful for wireless networks in optimizing load balancing, routing, energy management, and even some self-behaving properties like self-organization. This work's contribution is that it associates the synchronized movements and connectivity aspects among vehicles as well as the connectivity resistance and synchronization, whereas the proposed and developed scheme increases the end-to-end file sharing efficiency for delay sensitive streams in vehicle MP2P devices. The scheme extends the advantages offered by the Hybrid Mobile Infostation System (HyMIS) architecture proposed by Mavromoustakis and Karatza, in [6], where the Primary Infostation (PI) is not static but can move according to the pathway(s) of the roadmaps. HyMIS adopts the basic concept of pure Infostation system in terms of capacity service node but it avoids flooding the network with unnecessary flow of information. This capacity node plays a role of control storage node as Haas and Small mention in [7]. Taking the advantages of the proxy caching work done by Liu and Xu in [8] this work proposes an exploitation of the mobility characteristics of each user by selecting the MI peer to be dynamically selected according to characteristics such as the residual capacity of the device based on the push-based activities by other nodes. Heavy emphasis of this work has been put on push-based dissemination explored in [9] by Little and Agarwal, and in [10] by Lochert et al, and analytical dissemination through vehicle-to-vehicle propagation proposed by Wu, Fujimoto and Riley [11] as well as on some recent findings on practical systems as in [12], [13] by Lee et al, and Mahajan et al respectively, for pull-based diffusion activities. The scheme is proposing a index-based mechanism which will enable the selection of the *MI* in a cluster *L*. The following section explores the passive synchronized mobility model in the end-to-end path and presents an analytical model for the end-to-end capacity estimations.

III. SYNCHRONIZED MOBILITY MODEL IN THE END-TO-END PATH AND CAPACITY CONSIDERATIONS

A. *Communicating scheme in Vehicle-to-Vehicle communications*

The interactions with roadside equipment can likewise be characterized fairly accurately, whereas most vehicles are restricted in their range of motion, for example by being constrained to follow a paved highway. Automobile high speed information interexchange access would transform the vehicle's on-board computer to an essential productivity tool, making virtually any web technology-using pure Infostations) available in the car. However a significant aspect of wireless systems is the sudden partitioning of the connectivity, namely intermittent-connectivity experienced by nodes, where sudden network partitioning problems prevent the exchange of any requested information. Requested object replication and replicas redundancy face the requests' failures whereas they create severe duplications and aggravate the capacity of the end-to-end path. Figure 1 shows the proposed VP2P push and pull procedure in a path using the Passive Opportunistic Synchronized Approach (POSA) as follows: We have enabled a HyMIS configuration where the primary Infostation is not static (PI) but can move as the pathway allows called Mobile Infostation (MI). MIs enable recoverability for any requested object in the end-to-end path and it maintains the sharing reliability. As vehicles are moving from one direction to the other the *i-th* vehicle (MI) can pull requested resources to *i-1, i-2, i-3, i-k*, where *k* is the number of peer vehicle in the end-to-end path requesting resource R_i. Figure 1 also shows the proposed vehicular MP2P *push* and *pull* procedure where the *i-th* vehicle is assigned as MI and can pull requested resources to *i-1, i-2, i-3, i-k*, whereas the vehicle which the MI follows can then push any of these resources to the *i+1, i+2,* $i+MI_k$ vehicle (dash lines denote the push procedure which takes place and solid lines denote the pull procedure). Both procedures take place until the next and preceding MI is reached while *i-th node* is sharing resources, respectively. These notations can also be seen in a more clear form in the figure's 2 pseudocode, which shows a single step for the vehicle's MI transition.

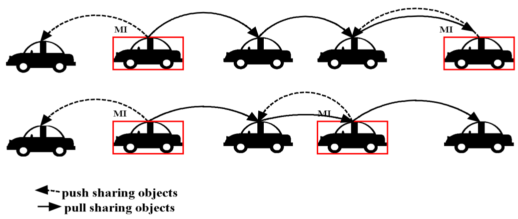

Figure 1. The push and pull configuration for Vehicular MP2P devices while moving in predetermined paths.

```
Set communication Path(A,B, N)
{
If (MI criteria meet==TRUE)
  Set MI in the Path(A,B, N);
else
  form Path(A,B, M) ∀M_i ∈ N
for (MI=i;i<k;i++ ) ∀MI_k ∉ MI_i
pull_requestedObj(Ob_id, Cap, Peers,
estimated_delay,reputation_degree);
 for (MI=j;j>k;j-- ) ∀MI_k ∉ MI_j
push_requestedObj(Ob_id, Cap, Peers, estimated_delay);

}
```

Figure 2. Pseudocode for a single round trip step for the vehicle's MI transition in order to enable object replication placement scheme between synchronized peers.

B. Multi-hop mobility model and user's capacity in the end-to-end path

Resources availability problems can be also faced using a local summary of the global system-or clustered information of the subsystem-by using the property –well-known in distributed systems, of the generically referred concept as aggregation by Renesse et al in [14]. MP2P systems require to guarantee the availability any requested resources as well as to enforce appropriate access control policies. In our application scenario we assume that a common lookup application is being used in order to enable nodes to interexchange locally the requested information objects. As a starting measure we estimate the synchronized cooperative movements of each vehicle by measuring the motion performed while measuring at the same time the reserved capacity by each vehicle. Since vehicles are moving in an organized and –sometimes- predictable way, the pull and push model aggravates the capacity of each device, as in a MP2P environment. Through the proposed sharing scheme for Vehicle-to-Vehicle communications as well as the additional parameters that are being considered, like the evaluated end-to-end relay epoch/latency, the mobility pattern and the time frame for the allowed promiscuous caching introduced in [15] by Mavromoustakis, the proposed model enables efficient capacity manipulation in the end-to-end relay region and efficient data manipulation in the intercluster communication.

By adopting the modified scheme of Mavromoustakis and Karatza [6] and enable the role of MI to be adjusted into the vehicular devices, the PI and MI are now implemented by a certain frontal vehicle and the connectivity, where only unidirectional sharing and connectivity occurs.

When mobility is considered, the design of efficient rendezvous data dissemination protocols for enabling efficient manipulation and availability of resources is complex, and the existing solutions do not consider the random probabilistic movements of devices while disseminating data. In order to measure the direction movement we enable a probabilistic model for the direction of the movement of each device. Each device is associated with a random variable which represents the direction movement. For the movement this work considers a probabilistic Random Walk in a predefined pathway represented as a Graph (G) where this G enables as a random variable the weights of these random movement. A device can perform random movements according to the topological graph G = (V,E) where it comprises of a pair of sets V (or V(G)) and E (or E(G)) called vertices (or nodes) and edges (or arcs), respectively, where the edges join different pairs of vertices. This work considers a connected graph with *n* nodes labeled *{1, 2, . . . , n}* in a cluster L^n with weight $w_{ij} \geq 0$ on the edge (i, j). If edge (i, j) does not exist, we set $w_{ij} = 0$. Each node moves from its current location to a new location by randomly (probabilistically) choosing an arbitrary direction and speed from a given range. Such a move is performed either for a constant time for a constant distance traveled. Then new speed and direction are chosen. In the probabilistic Mobility model is described as a memoryless mobility pattern because it retains no knowledge concerning its past locations and speed values. In this work a Probabilistic Version of the Random Walk Mobility Model is used as in [21] by Ibe. In this model the last step made by the random walk influences the next one based on the stationarity and the correlations between the movements. Under the condition that a node has moved to the right the probability that it continues to move in this direction is then higher than to stop movement. This leads to a walk that leaves the starting point much faster than the original random walk model. Given that the device/vehicle is currently at node *i*, the next node *j* is chosen from among the neighbors of *i* with probability:

$$p_{ij}^{L} = \frac{w_{ij}}{\sum_{k} w_{ik}} \quad (1)$$

where in (1) above the p_{ij} is proportional to the weight of the edge (i, j).

C. Cooperation model and end-to-end capacity using passive message ferries for delay sensitive streaming

In order to define which requested objects should be outsourced onto preceding m-peers a ranking model has been applied as follows: To find the rank of an object $a1\ a2 \ldots a_m$, one should find the number of objects preceding it. It can be found by the following function:

function rank($a_1, a_2, \ldots, a_m$)
rank← 1 ;
for $i \leftarrow 1$ **to** m **do**
for each $k<a_i$
$rank \leftarrow rank + N(a_1, a_2, \ldots, a_{i-1}, k)$

Then the new sequence will cache onto other nodes in the path the first *k*-requested objects where k is defined as a function of the remaining capacity onto each device as:

$$|k| = \inf\left(\frac{\sum_{N=i}^{N}(1-\rho_N)}{N}\right) \quad (1.1)$$

where ρ_N is the utilized capacity and N is the number of hops in the end-to-end path. Nodes in the path are moving according to the 2-D plane mobility model $L \subset \Lambda, \Lambda \subset \Re^2$. A moving square (the $\{\Lambda_1, \Lambda_2, \Lambda_3, \ldots\}$ bounded area) is divided into multiple sub-squares, called cells as in [1], and time is divided into slots of equal duration. At each time slot a node is in and can be only in one cell. The initial position of a node is uniformly chosen from all cells. At the beginning of each time slot, the node jumps from its current cell to one of its adjacent cells with equal probability. Two mobile nodes can communicate with each other whenever they are within a distance of *d*, the transmission range of the mobile node. In order not to have an optimistic assumption a low density population network is assumed with regards to the number of traversing nodes per Λ_i. We assume that no conspiracy policy exists where nodes somehow conspire together not to meet each other forever and move at *d>D* and in parallel.

The *index* of each node is being transferred using the message ferries that are passively passing from any other pathway within the distance of communication range of each device. Figure 3 shows this approach where the message ferries are crossing any other pathway and at the same time being in the distance transmission range of each device that they pass from.

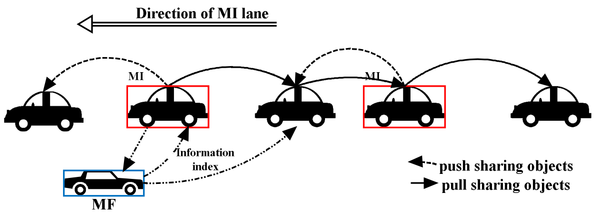

Figure 3. Passive message ferries where any other device can play the role of the messanger regarding the information index.

Taking into account the delay characteristics, let N be the number of source peers in the network (*N* different end-to-end paths) and $C_i(t)$ be the service capacity of source peer *i* at time slot *t*. An end-to-end download can be then depicted as a function of time as derived from Chiu and Young Eun in [16] and the $w^L{}_{ij}$ of the end-to-end path in the cluster L as:

$$T = \min\left\{ s_{ij} > 0 \mid \sum_{t=1}^{s} C(t) \geq F \right\} \tag{2}$$

where *F* is the file capacity defined as $\{f_1, f_2, f_3, f_4, \ldots f_n\}$ equi-divided file chunks and *s* a given end-to-end bounded allowed delay for this file to be downloaded from any numbers of peers in the end-to-end path. The obtained eq. (2) derived from Wald's equation introduced by Ross in [17] can therefore be expressed as:

$$F = \mathrm{E}\left\{ \sum_{t=1}^{T} C^L(t) \right\} = \mathrm{E}\{C^L(t)\}\mathrm{E}\{T\} \tag{2.1}$$

where we can easily extract the slotted amount of file chunks that are shared in the end-to-end path. The $A(\vec{c})$ is the minimum average capacity offered by each link in the path as:

$$A(\vec{c}) = \frac{1}{N}\sum_{1}^{N} \inf(C_{ij}(t)) \tag{3}$$

where $A(\vec{c})$ is the requested and available arithmetic mean for the capacity in the path. The average capacity offered by the end-to-end path considering all the links in the path of the requested file F, can be denoted as $A(\vec{c}) \big/ \mathrm{E}\{C_{ij}{}^L(t)\}$.the average download time is:

$$\mathrm{E}\{T_{F_{ij}}\} = \frac{F_c}{A(\vec{c})} = \frac{N \cdot F_c}{\sum_{1}^{N} C_{ij}(t)} \; \forall w_{ij} \in L \tag{4}$$

while it stands that for $C_{ij}(t) = \min(\inf(C_{ij}(t)) \big| \mathrm{E}\{T_{F_{ij}}\}$.

Let $t_\lambda = \max(\Theta_{MI,j})$ be the contact rate estimation and $\Theta_{MI,j}$ is the estimated contact time between MI and a moving node *j*, then it stands that a vehicle remains as a MI in the path if the following is satisfied:

$t_{\lambda_{ij}} \geq \dfrac{A(\vec{c})}{BW_{ij}}$ where $t_{\lambda_{ij}}$ is the contact rate in the path between i,j and BW_{ij} is the associated bandwidth in the path between i,j. The estimation of $t_{\lambda_{ij}}$ is essential since it can determine the time that a mobile node can remain as a MI.

D. Considering contact interactions for collaborative streaming

In this section we propose a number of social interaction parameters which take place in collaboration with the file chunk outsourcing of the previous section. The metrics are community-oriented and are considering the number of created clusters $C_N(t)$ in a specified Relay region of a certain transmitter–and a number of receivers (1, N] under the relay node pair (u,w $|MI_i$) -as a modified definition of [18]- as follows the:

$$C_N(t) = \frac{2|h_N(t)|}{|I_{C(N)}(t)| \cdot (|I_{C(N)}(t)| - 1)}, \text{ iff } P_{u \to w \to (x,y)} > W_N(t) \tag{5}$$

where *W* is the Community streaming factor and is defined as the number of existing communities in the intercluster communicational links at a given time instant. The $h_N(t)$ is the number of hops in the existing clusters and the $I_{C(N)}(t)$ is the number of interconnected nodes N in the cluster $C_N(t)$. *W* can be defined according to the download frequency of the file chunks in the intercommunity as follows:

$$W_N(t) = \frac{DldRate \cdot \#\, sharingChunks}{Total\#\, dlds(t) \cdot \#\, inactiveChunks} \tag{5.1}$$

where in (1.4) the download rate is considered in contrast with the number of chunks being shared in a specified instant time *t*.

IV. PERFORMANCE EVALUATION, EXPERIMENTAL RESULTS AND DISCUSSION

A. Dedicated Short Range Communications (DSRC)

To emulate the scenario described earlier, the need of a possible realistic environment must be achieved. DSRC was used for the evaluation of the proposed scenario which is two-way short- to medium-range wireless communication channels specifically designed for automotive use and utilizes a corresponding set of protocols and standards [19]. Considered to be short to medium range communication technology it operates in the 5.9 GHz range. The Standards Committee E17.51 endorses a variation of the IEEE 802.11a MAC for the DSRC link. DSRC supports vehicle speed up to 120 mph, nominal transmission rage of 300m (up to 1000 m), and default data rate of 6 Mbps (up to 27 Mbps). This will enable operations related to the improvement of traffic flow, highway safety, and other Intelligent Transport System (ITS) applications in a variety of application environments called DSRC/WAVE (Wireless Access in a Vehicular Environment). In the evaluation of the proposed scheme we evaluated the Peer-to-Peer/Ad hoc mode (vehicle–vehicle) scenario and took into account the signal strength parameters and the minimized ping delays between the nodes in the end-to-end path according to the $d_p = Min\sum_{i=1}^{n} D_i$, where *D* is the delay from a node *i* to node *j*, and d_p is the minimized evaluated delay in the end-to-end available path. Moreover, considering the need of bandwidth for the wireless devices, it is necessary to apply efficient routing algorithms to create, maintain and repair paths, with least possible overhead production. The proposed scenario uses the Zone Routing Protocol (ZRP) [20]. The number of nodes varies depending on the mobility degree and the distance variations of each user within a connectivity scope. The user's transition probability arises from a specified location where certain information is pending to be received by this user.

B. Simulation results of the proposed scenario and discussion

In this section, we present the results extracted after conducting the discrete time performance evaluation through simulation of the proposed scenario. The simulation used a two-dimensional network, consisting of 100 nodes dynamically changing the topology on a non-periodic basis (asynchronously as real time mobile users do). For each node, it stands that after random time each node moves at a random walk to one of the possible destinations (north, east, west, south) in an organized vehicular way. Each link (frequency channel) has max speed reaching *10Mb per sec.* The propagation path loss is the two-ray model without fading. The network traffic is modeled by generating constant bit rate (CBR) flows. Each source node transmits one 512-bytes (~4Kbits) packet. Packets generated at every time step by following Pareto distribution, destined for a random destination uniformly selected. Nodes have at any time measures of the information destined for each node (for a given time interval) sent by any node.

Figure 4 shows the network dimensions with the data and capacity exchanged through the created clusters. Figure 4 shows that even when the files that are being exchanged are greater than the network dimensions, the proposed scheme effectively handles the end-to-end transmissions and enables the complete download whereas for this evaluation two measures were taken into consideration: the data exchanged within the cluster *i* and the data exchanged with other clusters.

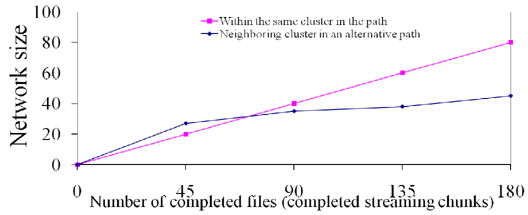

Figure 4. Dimensions of the network with the data and capacity exchanged through the clusters formed.

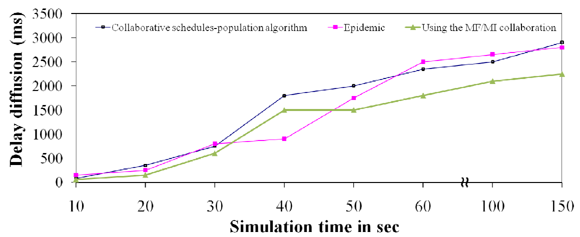

Figure 5. The delay of the diffusion outsourcing process with the simulation time compared with Epidemic and collaborative schedules schemes.

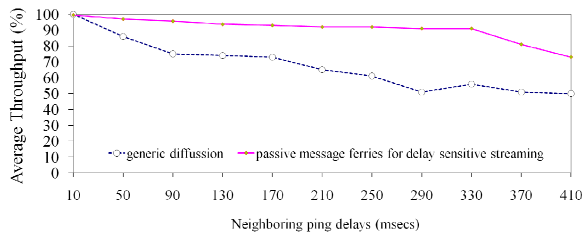

Figure 6. The average throughput with the neighboring ping delays.

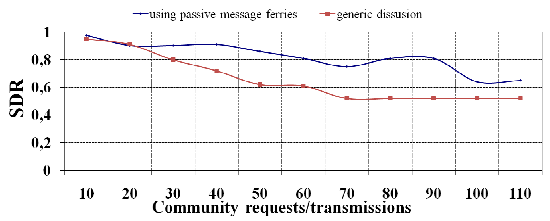

Figure 7. The SDR with the community/cluster requests using passive message ferries and the generic diffusion methods.

Figure 5 shows the delay of the diffusion outsourcing process with the simulation time compared with two different in implementation schemes: the epidemic and collaborative schedules schemes. It is easily spotted that fig. 8 shows the supremacy of the proposed scheme for this specific scenario in vehicular P2P systems whereas it shows the effectiveness with the significant robustness in the delay diffusion process-which is further minimized.

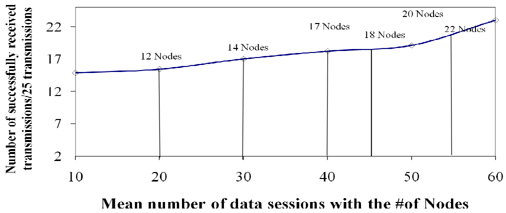

Figure 8. The number of successfully received transmissions over of total /25 transmissions with the mean number of sessions created in the system.

Figure 6 shows the average throughput with the neighboring ping delays comparing the proposed passive message ferries scheme and the generic diffusion cluster scheme. Figure 7 shows the SDR with the community/cluster requests using passive message ferries and the generic diffusion method, whereas in figure 8 the number of successfully received transmissions over of total of 25 transmissions in the path/clustered end-to-end transmission is shown, with the mean number of sessions created in the system. Finally, figure 9 depicts that neighboring feedback can enable better streaming stability in a multistreaming end-to-end path.

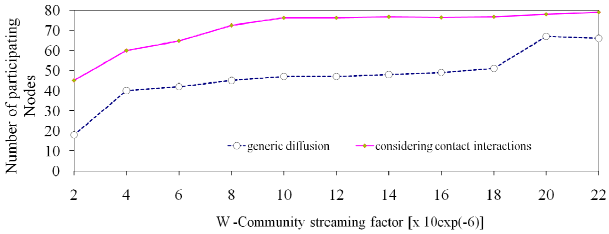

Figure 9. Number of participating nodes with the W.

V. CONCLUSION AND FURTHER RESEARCH

In this work, we have proposed a resource assignment approach while synchronized in-motion nodes are exchanging resources with bounded end-to-end delay. The method encompasses the assignment of the moving-so called-Mobile Infostation (MI) peer to a certain vehicle whereas this is done with the introduced Message Ferry (MF) mobile Peer in a unidirectional way. Passive message ferries are utilized as a resource index for the end-to-end path in order to efficiently enable delay sensitive streaming. Simulation results have shown that the scheme offers high throughput and significant end-to-end reliable exchange of resources whereas it offers high SDR for completed files.

Current and future research directions include the modeling of the mobility pattern of the peers by using approaches like the fractional Brownian motion taking into account the global requests and different network partitioning parameters as well as evaluating an extended version of the proposed scheme in real time.

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