Modelling Granule Dependent Information in Vehicular Ad Hoc Networks

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1. Introduction

This paper presents a novel simulation model which incorporates traffic simulation model and a Vehicular Ad Hoc networking model to achieve temporal and geo-spatial information granules formations simulation for the vehicles in the urban traffic networks in real-time using the concepts and techniques of Granular Computing theory.

The Granular Computing theory describes the formation and the inherent features of the so-called Information Granules – basic units for aggregation of Knowledge Information carrying essential for the modelling system data. It has its formal foundations firmly based on using Fuzzy Sets, Rough Sets, Set Theory among other mathematical fields. [6][7][10][11][12][13][14][15] .

We propose to combine Vehicular Ad Hoc Networks (Vanet) [1][2][3][4][5] and Granular Computing methods collaboratively to investigate the basic principles for knowledge granulation in traffic systems. We present here our achievements in determining fuzzy information granulation as localized distributed information granules within the system and we also present the identified different levels in performing system data granulation.

The overall aim of the simulation is to process in a hierarchical way traffic information data generated in the traffic system to mimic a human-like abstraction process using fuzzy set theory and granular computing.

Central to the simulation approach is the so called Car-to-Car (C2C) type of communication. It represents the possibility of cars communicating with each other directly and self-organising themselves into communication networks – the so called ad-hoc networks. As well as avoiding building expensive roadside infrastructure nodes, this approach elevates on a different level the concept of distributive data generation and control. This approach illustrated on Fig 1. however brings its own challenges and problems.

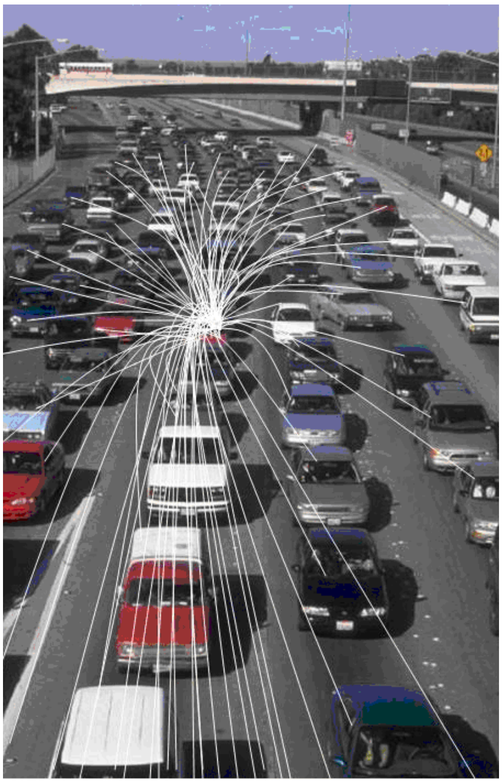

Figure 1 - Vehicular Ad-hoc network formation and dissipation

We are going to utilize vehicular ad hoc networks to form a decentralized real-time environment in which data will be granulated into knowledge and used in real-time as it ripples through the network. We also assume that data is relative to time and environment. Same data can be part of different information granules at different levels. Different information

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granules are also relative to their strata in the hierarchy and only meaningful in current context.

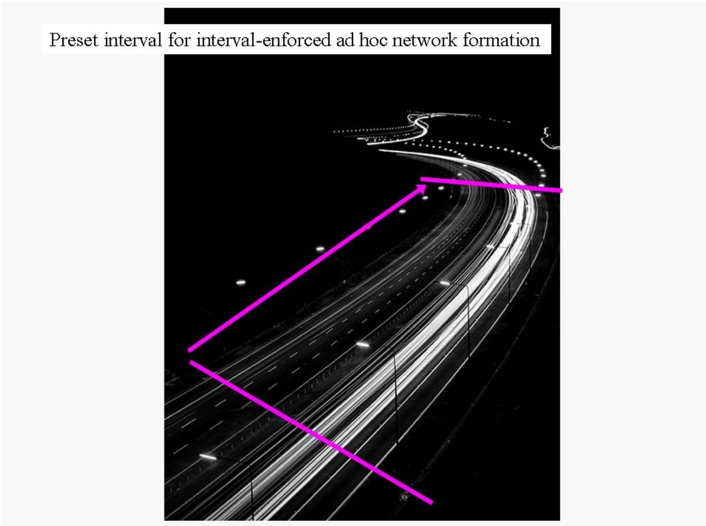
The simulation assumes that each vehicle is equipped with ad-hoc communications capabilities with necessary range and there is GPS and a telematics computing device on board. Each vehicle has a map of the urban area loaded in its GPS device and vehicle is aware of its position during its travel.

The simulation of the Vehicular ad hoc network (VANET) formation is based on the ability of the telematics platform software in the vehicles themselves to form ad-hoc networks by triggering ad hoc network formations in preset geographic locations and preset times. Vehicles will have this information preloaded in their telematics platforms. The simulation of the Vanets formation then is used to obtain knowledge granules (useful pieces of traffic information) as a result of inter-vehicle communications and in-vehicle calculations. Network formation and persistence issues are built around this process. There are also two aspects to formation of the ad-hoc networks. First, roads on the inbuilt map are divided into road granules. Vehicle has the necessary calculation algorithm in its telematics system to link its position to the relevant road granule. Second element is information granulation schedule. This schedule is a mapping of all the roads to calculation times. Vehicles constantly know their current position and which road granule it is on. When there is a calculation to be performed on the road its only for the vehicles form temporary vanets only and the duration of the calculations is only for the road granules they are currently in. Those road granules geographically restrict the network boundaries. A road may have many road granules and hence many vanets independent of each other. Each vanet performs its own calculation and obtains its own information granule result for its road granule. We can think physically of a road granule as a road segment.

Information in the vanet formations is granulated using Granular Computing concepts. The problem domain of collaborative generation of information is fuzzy in nature. As a result the vehicles in a road segment form ad hoc networks within the pre-defined road granules and they do periodic calculations and aggregations using the formal techniques of Granular Computing and Fuzzy Granulation.

Each vehicle has an intelligent module called Network Granulation Engine. This module tracks its GPS location and matches the position to the in-built map roads and road intervals.

The Network Granulation Engine, then establishes, maintains and re-establishes all necessary ad hoc network links in accordance with the network logic and the underlying protocols.



A simulator has been developed to help with the design and the evaluation process of the model. The simulator has provided a lot of insight information into the model and during the development; it has helped to consider the model in different aspects. The development process of the simulator itself has acted as a brain storming exercise which helped to refine and shape the model.

2. Simulator Design.

Simulator has been designed to be modular to include the data from the GIS, to be an urban traffic simulator and on to superimpose onto that the network granulation engine and the information granulation engine. The urban traffic simulator generates and simulates traffic while the network granulation engine generates geographically bound ad hoc networks and arranges the infrastructure for data communications. The information granulation engine then makes use of the data within the ad hoc network to generate human-centric fuzzy information granules.

Each network is formed reactively to do periodical calculations and a network head is selected for the duration of one cycle of calculation.

The simulator consists of three major components. The first component is the traffic simulator. This component includes a user Interface, loading and processing NTF based Ordnance Survey map data, synchronizing the data wit the Nottingham City Map and simulating traffic movement on the map. A basic traffic simulation is produced for this to form the basis of vanet based information granulation.

On top of the traffic simulator module two more components are developed as the Network Granulation Engine and the Information Granulation. The network granulation engine utilizes the road and vehicle object in the underlying traffic simulation module and granulates the roads into network granules. Each network granule maps to a physical road segment. This road granule identifies a vanet. Vanets are geographically enforced. Each vehicle knows its current position and when a calculation is triggered vehicles form vanets to perform the calculation triggered. The simulator places each vehicle from the underlying simulator into road segment objects and performs information granulation on this abstraction. Network delay is simulated as simulation cycle delay. The Information Granulator Engine takes a copy of the current state as vehicles on a road network granule, waits necessary number of cycles after which it checks vehicle positions and finds out the vehicles that have moved during this wait time and removes them from the initial state and performs the calculation on those vehicles that are still in the granule. In this way network formation latency is considered for the connection timing in the granule.

The described above component based granular structure allows different aspects of the system to be simulated independently.

One study that can be done using the simulator is the percentage of connection maintained by the granule size. As the model enforces geographically formed vanets there are two major questions regarding the infrastructure of the system that are obvious intuitively. Those are: What would be the ideal speed to maintain the highest possible connectivity during a short vanet formation and information granulation process and secondly, what will be the ideal network granule length on the road. The simulation presents the results from the simulation runs with different network granule lengths that are studied with the speed kept at 40 mph, 50 mph, 60 mph and 70 mph.

After simulating connectivity for the entire grid, first thing that came clear was the fact that road lengths in a city did not always allow for road granule lengths specified. After applying certain granule length, increase in granule length started to have less effect on connectivity as many roads did not have enough length for the specified granule lengths and also many of the roads would have some short granules left at the end. When having the combination of road end short granules and short roads, after certain value of the granule length parameter the granule length increases do not affect the connectivity in the overall system shown in Fig. 2.

The total number of vehicle objects involved in each simulation is approximately: 13200. Vehicle objects are generated periodically, based on a road saturation constant and vehicles coming to the end of a road are destroyed. Vehicle speed is set as 40 mph, reflected in the simulation cycles and movement on each cycle.

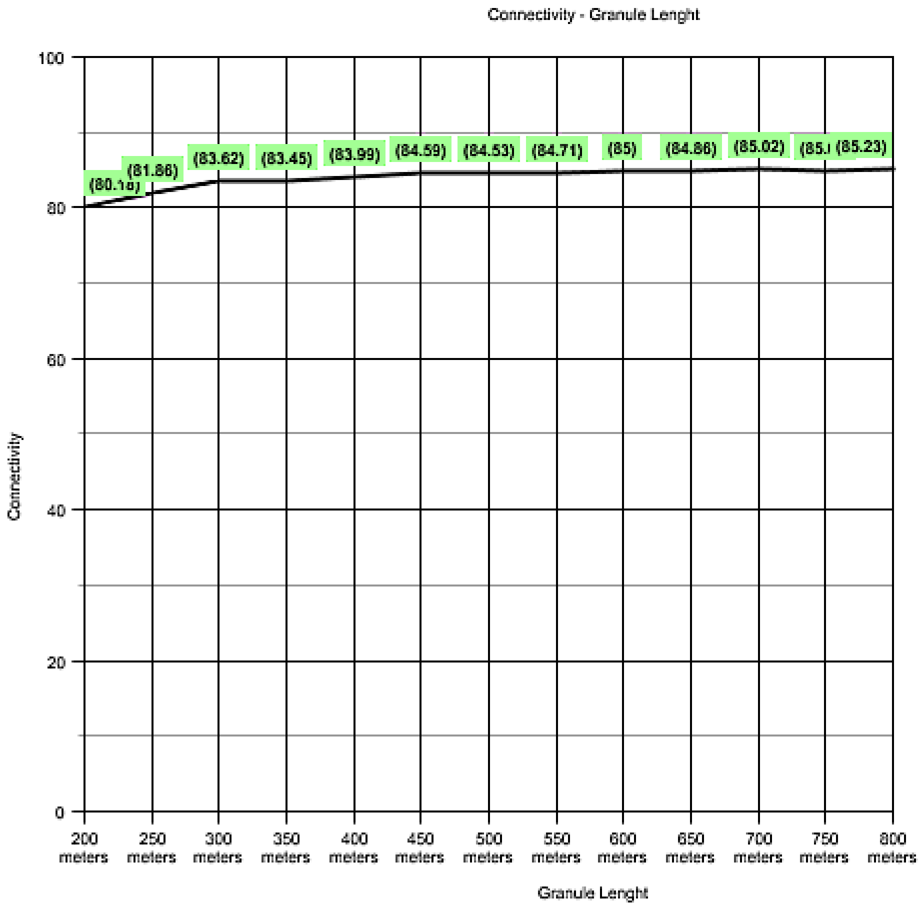
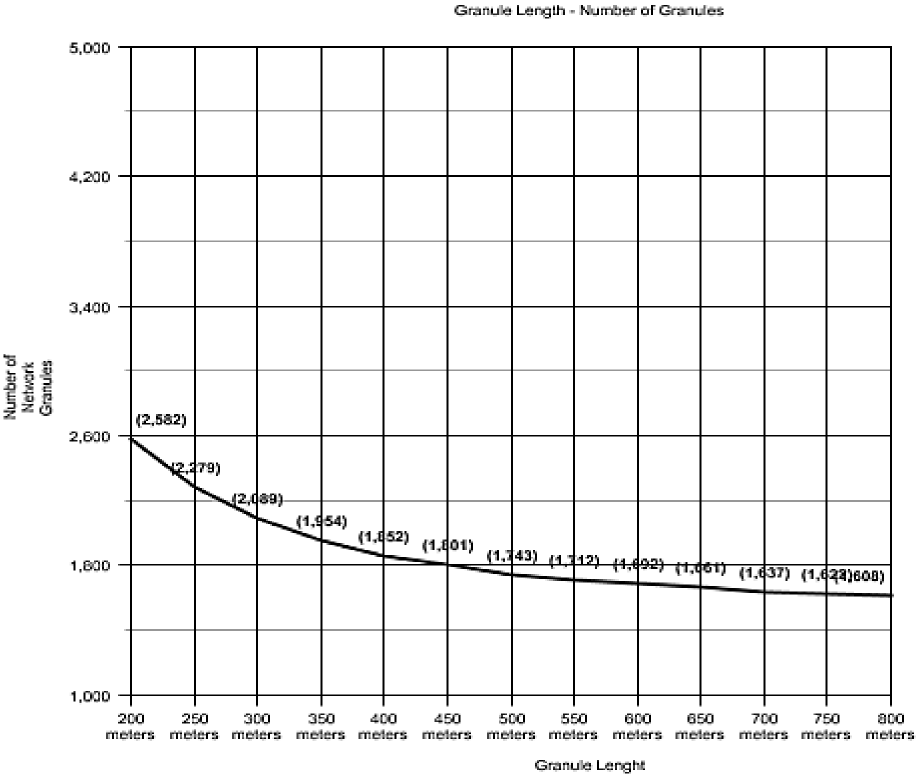


Figure 2. Connectivity – Granule Length graph. Connectivity is as percentage. This is the connectivity maintained fro the duration of the network calculation.

Granule Length	**Connectivity Maintained**
200 meters	80.18 %
250 meters	81.86 %
300 meters	83.62 %
350 meters	83.45 %
400 meters	83.99 %
450 meters	84.59 %
500 meters	84.53 %
550 meters	84.71 %
600 meters	85.00 %
650 meters	84.86 %
700 meters	85.02 %
750 meters	85.01 %
800 meters	85.23 %

It is clearly visible from the graph that, increasing the road granule sizes does not result in equivalent linear increase in connectivity in the overall urban system.

Another variable studied in this research was the number of the road network granules in the system and how they changed with road granule length enforced. This shows a much sharper decrease initially but slows later. Longer granule lengths mean larger ad hoc network areas and more vehicles getting involved but loss of vehicles do not decrease as such. Loss of vehicles during calculation cycle happens when vehicles exits the current road network granule and enters into the next one during the calculation process. Vehicles close to the exit edge will get out of the granule during a calculation. Increasing granule length gets more vehicles involved and less percentage gets out of the edge. When the two graphs are compared this correlation can be observed.



Granule Length	Number of Granules
200 meters	2582
250 meters	2279
300 meters	2089
350 meters	1954
400 meters	1852
450 meters	1801
500 meters	1743
550 meters	1712
600 meters	1692
650 meters	1661
700 meters	1637
750 meters	1622
800 meters	1608

3. Information Granulation

The Knowledge Granulation Engine - the data processing and knowledge generation module resides on top of the Network Granulation Engine.

While the underlying Network Granulation Engine establishes and maintains the network and deals with data flow, the Knowledge Granulation Engine processes the traffic data.

Concepts of Granular Computing are utilized for Knowledge Generation.

Ad Hoc Networks at each interval act as a coherent unit, to perform one calculation at set periods and produce a single Information Granule each time, from data received from vehicles.

This knowledge is then relayed to the Control Centre and drivers in different ways. Road side gateways are assumed to be used to obtain and relay information granules.

4. Conclusion

From our study into the two developing fields of study, Granular Computing and Vehicular Ad Hoc Networks we have come across several significant features in support of our vision. We have designed the architecture of a hierarchical real-time information system of imprecise data form the Urban Traffic System. We have established an original data processing system utilizing both fields of study.

A Vehicular Ad Hoc network level communications protocol is envisioned which will cater for the inter-vehicle intelligent knowledge generation.

Utilizing the techniques of intelligent information processing in the field Of Granular Computing, the imprecise and dynamic conditions of the Urban Traffic System can be dealt with in the way of forming a truly scalable, real-time and useful Urban Traffic Information generation and processing system. The architecture we have developed looks promising and has the potential to overcome the underlying difficulties of the imprecise and dynamic nature of the Urban Traffic System.

The proposed system architecture has been developed as a prototype solution scenario for real-time handling of infinite amount of data. This is also a roadmap and project plan for our future work.

5. Future Study

In the next stage we are going to develop a vehicular ad hoc networking communications protocol and test it.

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