Personal Mobile Intelligent Travelling Assistance System

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Abstract

The research program “Seamless Multimodal Mobility” of the research school TRAIL is aimed at developing new (public) transport services for the future. The SMART ROAD project is focused on road traffic support and guidance systems. In both programs the Personal Intelligent Travelling Assistant (PITA) plays an important role. The PITA is an application running on a handheld device, providing communication between travellers, public transportation companies and road information systems. The goal is to provide the user with an up-to date personalized travel advice. Many communication networks are involved, Internet, GSM, Wireless LAN, GPS. In this paper we present the design of the PITA system and how it provides dynamic routing information to the user. Our dynamic routing in traffic networks and mobile networks is based on the Ant Based Control algorithm.

1. Introduction

In the Netherlands one million people use public transportation every working day. The railroad network is overloaded and minor incidents lead to a large amount of consecutive delays. Information on delays is available at the railway stations or provided by telephonic information systems. Usually, only static information is available. In case of delay it is not easy to find an optimal route based on dynamic data to the planned destination. Even more people travel by car every day. In the rush hours we observe traffic congestion on the highway and in the cities.
One approach to reduce travel time for individual travellers would be to develop a route planner that incorporates traffic information and public transport possibilities when searching for the fastest route. If congestion occurs along the normal route, this planner will search for the best alternative, which may lead the traveller along other highways, but may also advise the traveller to drive to the nearest train station.
Another important issue is the increasing number of accidents, caused by unexpected events on the roads or changing weather condition. Travellers need personal, up to data information to reach their goals in a safe and fast way.
In recent years a lot of effort is carried out to solve these traffic problems. At TUDelft there are running some research programs, aimed at solving scientific, business and societal problems in the field of transport, logistics and associated infrastructure. A crucial issue is the communication between travellers, and information system and the communication structure itself. We will first describe the current research programs. Next the routing system and results of an experiment will be presented. The paper ends up with conclusions.

2. SmartRoad

SmartRoad was introduced as a low-cost traffic control system, that can offer a completely new dimension in traffic control and road safety by making the road

intelligent [1], [8]. Large numbers of small autonomous sensors installed in the road together form a complete traffic control system. Each sensor unit is a standalone intelligent system with configured processors, application specific hardware for detecting traffic and wireless communication.
The initial idea of SmartRoad was to create a warning system for roads without any type of detection and control system. SmartRoad would make it possible to warn and assist individual vehicles without the need for special equipment in the vehicles. Especially secondary roads can benefit from this system while the SmartRoad concept is expected to be much cheaper than existing ILD-systems, which are much too expensive for secondary roads.
The original idea of SmartRoad was to implement intelligent sensors in the familiar cat-eyes in such a way that they can warn individual human drivers for dangerous events and assist these drivers along the road-network. With numerous SmartRoad-elements in the road surface a complete picture is available of the vehicles where about on the roads. With this knowledge the interactions between the vehicles in a traffic stream can be observed more accurately than is possible with only a few vehicle detectors. In this way the proposed SmartRoad system can give advice to the road users and organize traffic in such a way that quick and more comfortable travelling through urban road networks is possible. The SmartRoad system can do this because it has more information than the individual road-user, because it gets information of many vehicles from the numerous sensor-elements.
Interactive SmartRoad is the concept that has arisen from the original system-concept: to guide, warn and regulate traffic by creating a feedback from the traffic control system to the individual human driver, and thus making the driver part of the control system.

3. PITA

The research program “Seamless Multimodal Moblity” of TRAIL at Delft University of Technology is aimed at developing new public transport services for the future. The traveller will be transported from door to door without having to spend time on finding the best route to his destination or worrying about delays or calamities while using public/private transportation. Applying the results of the SMM program to current transport systems will result in drastic changes in these transport services as new transport modalities and transfer nodes will be introduced and transport services will be provided on a more demand-driven and less fixed basis.
Within the research program SMM, the personal Intelligent Travelling Assistant (PITA) plays an important role. The PTA is an application running on a handheld device, providing communication between travellers and information companies. It provides the user with an up-to-date personalized advice on what public/private transportation to use, based on current delay information available. A key aspect is that the travellers themselves mainly provide this information. The PITA has the following properties:
- travelling assistant
The PITA will continuously provide the user with the best advice about what transportation to use, to reach its destination, depending on his travelling preferences, his current location and available delay information. The advice is already available before the user starts to travel and the advice will be updated continuously while the user travels, depending on delay information or other

updated dynamic information becoming available. Also possible alternative routes will be generated and can be requested by the user.

- intelligent assistant

The PITA will continuously monitor the delay information and determine the significance of the user. If the delays affect the journey of the user, the system will generate alternative routes, estimate the travelling time and the risks on those routes and select the best possible option for the user to use. This releases the user from scheduling his journey and lets the user blindly trust the generated personal advice. Finally it is possible to interact with the PITA system in a multi-modal fashion. This gives the user the possibility to speak to the system when in a hurry, or to click and point on the handheld in case of a noisy environment. The system can also give multi-modal feedback, by displaying the advice or read it aloud using speech synthesis.

- personal assistant

Not only the application run on a personal device of the user, the application will also represent the user to the rest of the system. The system can learn the preferences of the user from day tot day. In fact the PITA handheld will be a digital copy of the user, functioning on the basis of the preferences of the user and responsible for all requests to the system.

- user location for delay information

Crucial to the success of the PITA, is the availability of accurate delay information and other information affecting the journey of the user. Sometimes the information will be supplied by public transport companies or by congestion information systems. However because this data is very distributed and usually not real time available, the system has to able to function without this information being made available. Since all users of the system have their own handheld with them, the system will use positioning technology with the handheld to determine the position of the user on the basis of the position of the handheld. The position of the handheld is made available to the rest of the system, which can determine the delay the user is experiencing. This information is not only used to optimise the advice for the user itself, but also to advice other users. In this way the PITA system can generate the delay information by itself.

- ad-hoc information optimisation

The PITA handheld has to connect to the rest of the system and several other information sources to combine the information in an optimal advice to the user. Depending on the devices (i.e. GSM, Wireless LAN device or GPS device) a user carries with him, the system will choose the optimal connections for acquiring information about the user's location, train schedules, congestion information, weather information and possible delays. Once the user has configured the available connections, the system will optimise the bandwidth usage and minimize costs. Also the possibility of ad-hoc networking between the handheld devices and sharing available information in an ad-hoc network (based on Wireless LAN) is used.

- traveller flow planning

With he PITA system, traveller's flows can be predicted, because the systems know the position of its users.

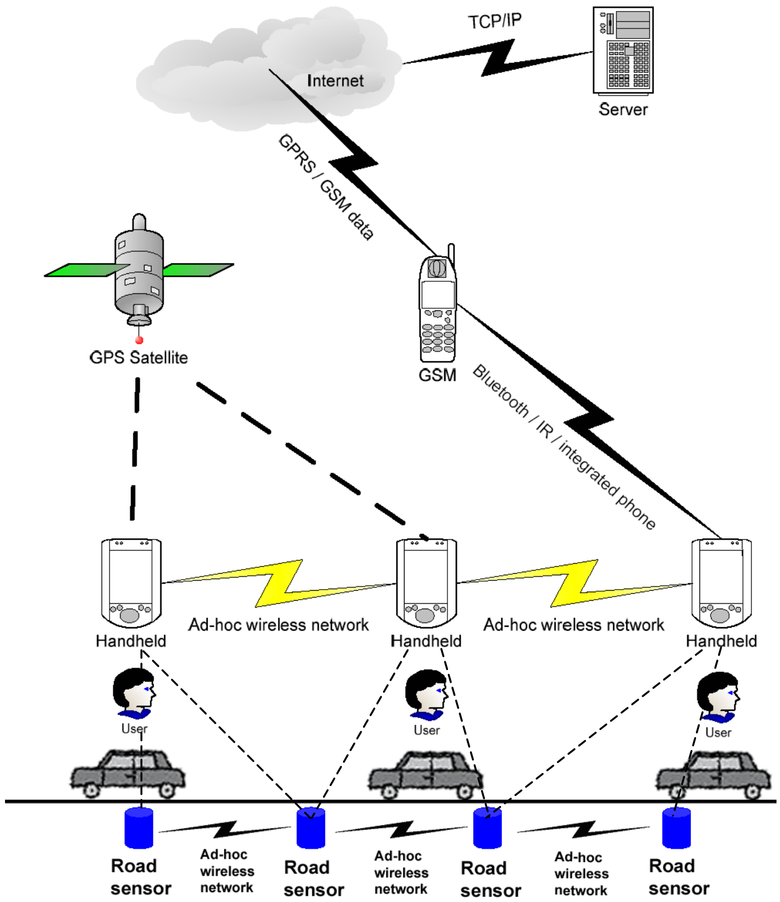

Fig. 1. Different communication networks involved in the PITA

4 Ant-based control for network management

We can use the idea of emergent behaviour of natural ants to build routing tables in any network. We will apply it in a traffic network in a city, i.e. the composition of the roads and their intersections. This network is represented by a directed graph. Each node in the graph corresponds to an intersection. The links between them are the roads. Mobile agents, whose behaviour is modelled on the trail-laying abilities of natural ants, replace the ants. The agents move across the network between randomly chosen pairs of nodes. As they move, pheromone is deposited as a function of the time of their journey. That time is influenced by the congestion encountered on their journey. They select their path at each intermediate node according to the distribution of the simulated pheromone at each node. Each node in the network has a probability table for every possible final destination. The tables have entries for each neighbouring node that can be reached via one connecting link. The probabilities influence the agent's selection of the next node in their journey to the destination node. The probability of the agents choosing a certain next node is the same as the probability in the table. The probability tables only contain local information and no global information on the best routes. Each time an agent visits a node the next step in the route is determined. This process is repeated until the agent reaches its destination. Thus, the entire route from a source node to a destination node is not determined beforehand. Agents are launched at each node with regular time intervals with a random destination node.

5 Routing problem

The most important problem of dynamic routing is solved by the timetable updating system and the route finding system. These two subsystems together form the routing system. The function of the route finding system will be clear: we are building a system to route vehicles. The reason why we need the timetable updating system is the following. The route finding system needs information about the state of the network. A static route finding system could use a fixed set of data, but we will use a dynamic route finding system that needs dynamic data. Those data are provided by the timetable updating system.

That information can be for example the load of the parts of the network but a more direct and therefore more practical type of information is the time it takes to cover a road. Vehicles send information about their covered route to the timetable updating system. From that information this system computes the traveling-times for all roads and stores it in the timetable in the memory. Besides the timetable also a history of measurements is stored in the memory. The route finding system uses the information in the timetable to compute the shortest routes for the vehicles. When the vehicle requests route information, the route finding system sends this information back to the vehicle.

6 Route finding system

This system uses the AntNet algorithm [4]. Routing is determined through complex interactions of network exploration agents. These agents (ants) are divided into two classes, the forward ants and the backward ants. The idea behind this subdivision of agents is to allow the backward ants to utilize the useful information gathered by the forward ants on their trip from source to destination. Based on this principle, no node routing updates are performed by the forward ants, whose only purpose in life is to report network delay conditions to the backward ants. This information appears in the form of trip times between each network node. The backward ants inherit this raw data and use it to update the routing tables of the nodes. As all the algorithms inspired from ants life, AntNet uses probability tables. Besides these a node i keeps a second data structure, which its main task is to follow the traffic fluctuations in the network. It is given by an array $M_i(\mu_d; \sigma_d^2; W_d)$ that represents a sample means μ_d and variance σ_d^2 computed over the packet's delay from node i to all the nodes d in the network, and an observation window W_d where the last packet's best trip time towards destination d are stored. Our network model differs from the packet switch network for which AntNet was designed. There are no packets running in our network. It also has no buffers in nodes, and an infinite bandwidth is available on the links. The links still have a virtual delay provided from the time tables. The delay represents the necessary time for a car to cross the link. We adapted AntNet for our traffic network. The algorithm works as follows:

1. The mobile agents $F_{s \to d}$ are launched at regular time intervals from every network node s.
2. Each ant keeps a memory about its path (visited nodes). When an ant arrives in a node i, coming from node j, it memorizes, the identifier of the visited node i, and the virtual delay of the link (the trip time necessary for a car to travel from

intersection j to intersection i). These data are pushed onto the memory stack $S_{s\to d}(i)$.
3. When an ant comes in the node i, it has to select a next node n to move to. The selection is done according with the probabilities P_d.
4. If a cycle is detected, that is, if an ant is forced to return to an already visited node, the cycle's nodes are popped from the ant's stack and all the memory about them is destroyed.
5. When the destination node d is reached, the agent $F_{s\to d}$ generates another agent (backward ant) $B_{d\to s}$, transfers to it all of its memory, and dies.
6. The backward ant takes the same path as that of its corresponding forward ant, but in the opposite direction. At each node i along the path it pops its stack $S_{s\to d}(i)$ to know the next hop node.
7. In every node i, the backward ant $B_{d\to s}$ updates the data structures of the node: the local traffic statistics and the routing table for all possible paths (these are via all neighbors of the node i) with the destination node d, and, if $T_{i\to d} < I_{sup}(d)$, also the sub-paths of $s\to d$.

$$I_{sup}(d) = \mu_d + z\frac{\sigma_d}{|W_d|} \quad (1)$$

$$z = \frac{1}{\sqrt{1-\gamma}}, \ \gamma \in [0,1) \text{ gives a selected confidence level.} \quad (2)$$

The probabilities are updated with a reinforcement value. This is a function of the time $T_{i\to d}$ the ant computed and the local stochastic model of traffic in the node.

$$P'_{dj} = P_{dj} + r(1- P_{dj}) \text{ when } j = n \text{ the next node chosen by the ant} \quad (3)$$

$$P'_{nd} = P_{nd} - rP_{nd}; \text{ for } j \neq n \quad (4)$$

The reinforcement value r is computed as follows:

$$r = c_1\frac{I_{\inf}(d)}{T_{i\to d}} + c_2\frac{I_{\sup}(d) - I_{\inf}(d)}{(I_{\sup}(d) - I_{\inf}(d)) + (T_{i\to d} - I_{\inf}(d))} \quad (5)$$

$$r = \frac{1+e^{a}}{1+e^{\frac{a}{r}}} \quad (8)$$

where $I_{inf}(d) = min\{W_d\}$, the best value in the observation window W_d.
8. When the destination node d is reached, the agent $B_{d\to s}$ dies.

In the mapping function for r we skipped the $|N_i|$ factor present in the AntNet. This is because we want to have small values for r and less fluctuation in the probability tables. In the packet switch networks one of the aim of the routing algorithm is to use the bandwidth capacity in optimal way. The packets are sent to the destination not necessary following the best route.
This can't be accepted in the car traffic environment. We can't send the cars on longer paths just for keeping away the congestion on the roads. They are not packets. The traffic jams should be avoided, but also the drivers want to reach their destinations in the shortest possible time. So, the Routing system computes the optimal path for the vehicles choosing, all the time as next intersection, the one with the higher entry in the probability table.

7 Results

As a proof of concept we run experiments in a simple traffic network as displayed in Figure 2. The cars are generated on the middle of the roads and their destination is the middle of another link. We simulate an accident on the lane between nodes 11 and 7. This was done decreasing, after 1000 time steps, the speed on this lane from 50km/h to 15km/h. The traffic is generated from intersection 1/2 to 15/16 and vice versa. The default route for a car driving from 15/6 to 1/2 will be: 15-11-7-3-2. We expect that a queue will form on this lane and will grow affecting also the lane between nodes 15 and 11. All the roads having the same length, for the vehicles guided by the Routing system two alternative routes are available (15-14-10-6-2), (15-11-10-6-2). We expect these vehicles to follow one of these routes.

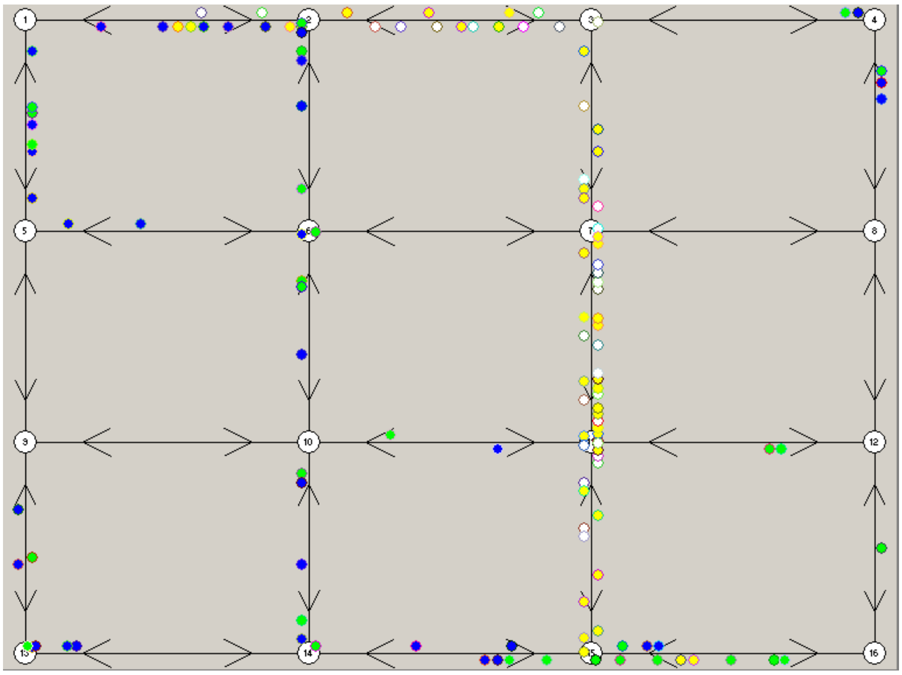

Fig. 2. Accident on the lane between nodes 11 and 7

The response of the routing system is very fast. Because two alternative routes are available, with the same length, some of the smart cars are routed even before the incident, on different routes. All of them are soon leaving the default path. But this leads to new congestion in the intersections 2 and 15 after around 4000 time steps. The response of the Routing system is to guide the cars to the destination via the nodes 1 and 16, so using longer routes. The average trip time is shrinking constantly for both types of cars. After 2000s we notice 144s for the smart ones and 166s for the cars that don't use the system, which means 12.5% difference (Figures 3 and 4).

This test proves the high performance of the algorithm that solves the two congestions. It guides the cars on a longer path in distance, but faster in time, even when two shorter alternative roads are available. The algorithm presented in [6], in the same situation, uses only the two short paths via nodes 2 and 15, resulting in big congestions in these intersections.

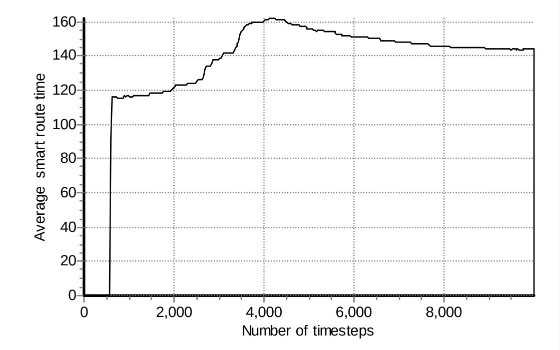

Fig. 3. The average trip time for the cars using the Routing system

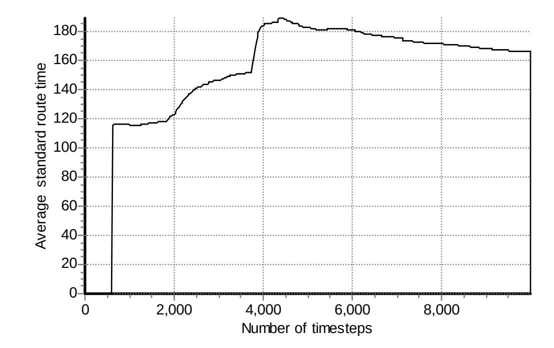

Fig. 4. The average trip time for the cars using the standard path

8 Future work

We started our research by designing and implementing simulation environments for dynamic routing using the ABC algorithm. We first applied this algorithm to dynamic routing Telecommunication networks [3]. Next we constructed a traffic simulation environment with a dynamic routing system based on Ant Based Control algorithm [6]. Vehicles are guided along the roads using the fastest way, taking into account the load on the roads. Next we assumed that car drivers are wireless connected by PDA devices. We designed and implemented a simulation environment of a MANET network on the top of our traffic simulation environment [9]. Again we used the ABC algorithm to construct the routing tables.
In the framework of the COMBINED project running at the DECIS lab in Delft, we created a simulation environment for crisis management integrating the ideas from the SmartRoad project and the PITA project.
In the next future we will test our systems with real life data. In the city of Berlin there was a project running on traffic management. During this project special vehicles were tracked for many days. This provides data about changing traffic load along the roads of the city. At this moment there is a first prototype available of the PITA system for public transport [8], [10].

References

1. P. Groeneveld. SmartRoad: a low cost traffic control system, Report TUD, (1995)
2. G. Di Caro, M. Dorigo. AntNet: A Mobile Agents Approach to Adaptive Routing, Technical Report 97-12, IRIDIA, Universit Libre de Bruxelles (1997)
3. R. Schoonderwoerd, O. Holland, J. Bruten, L.J.M. Rothkrantz. Load Balancing in Telecommunication Networks, Adaptive Behavior, vol. 5 no. 2, (1997)
4. G. Di Caro and M. Dorigo. AntNet: distributed stigmergetic control for communication networks. Journal of Artificial Intelligence Research (JAIR), 9, (1998), 317-365
5. L.J.M.Rothkrantz, J.C. Wojdel, A. Wojdel, H. Knibbe. Ant based routing algorithms, Neural Network World, Vol. 10, No.3, July (2000)
6. R. Kroon, L.J.M. Rothkrantz. Dynamic vehicle routing using an ABC-algorithm, Transportation and Telecommunication in the 3rd Millennium, Prague, May 26-27, (2003)
7. H.L. Voogd. Agents-framework design for SmartRoad, Report TUD, (2003)
8. M. Beelen. Distributed Intelligent traveling assistant, Report TUD, (2004)
9. B. Tatomir, L.J.M. Rothkrantz. Dynamic routing in mobile wireless networks using ABC-AdHoc, ANTS 2004, Brussels (2004)
10. R. van Vark. Personal Intelligent traveling assistant, PhD thesis, TUDelft, to appear in (2005)

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