Intelligent Transportation Systems using Mobile Grid Computing Technology

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***Abstract*: A system for highly efficient road transport management using ultra-high performance mobile computing technology is presented. The core component of the system is GUICD (Grid-based Ubiquitous Inter-vehicular Communication/ Computation Device).A GUICD once fitted in a vehicle acts as its electronic identity and makes it a node of a grid-based virtual supercomputer. This virtual supercomputer processes transport management data. The processed data can be used to intelligently control traffic lights and provide visual and auditory aids to the driver. How the whole system works and performs efficient transport management is described in this paper.**

Keywords - GUICD (Grid-based Ubiquitous Inter-vehicular Communication/Computation Device), Open Grid Services Architecture (OGSA)

I. The Need For Better Road Transport Management

Traffic is a growing problem in almost every city in the world. The average motorist spends 30 hours in traffic delays every year. The cost of traffic congestion per year in the world is $300 billion, representing the 14.5 billion hours of travel time and 20.8 billion gallons of fuel wasted sitting in traffic. Billions more have been spent on electronics and systems to alleviate this logjam. The system we present here provides an effective solution to this problem. Our solution, named GUICD (Grid-based Ubiquitous Inter-vehicular Communication/Computation Device), is based mainly on mobile communication and grid computing. Moreover it utilizes various other technologies from the fields of Embedded Systems, Routing Algorithms, Bluetooth and Air Traffic control.

II. A Brief Introduction to Mobile Communication

From a common man's perspective, the term "mobile communication" is restricted to mobile phones, cordless phones, pagers and so on. Technically mobile communication is defined as 'communication using devices that provide unrestricted freedom to the user to roam between different wireless networks' (Schiller).The greatest wave in the field of wireless communication came in the 19^{th} century due to scientists such as Michael Faraday, Heinrich Hertz and Nikola Tesla who were instrumental in developing the theory of electromagnetic transmission. But the concept now known as mobile communication started taking shape only during the early 20^{th} century through various innovations such as the train telephone, the mobile transmitter mounted on Zeppelins and the car radio. The world wars triggered various research projects in the field of mobile communication. During that period many countries around the world had developed ingenious standards for mobile communication across various radio bandwidths. Some of the more notable standards among these were NMT (Nordic Mobile Telephone), which operated at analog 450Mhz and served as a mobile communication standard for many European countries. NMT later developed into a new standard, which operated at 900Mhz and allowed roaming across Europe and was fully digital. This standard was called GSM (Groupe Speciale Mobile). In the US, AMPS was developed. This was an analog mobile phone system operating at 350Mhz. The German C-NETZ allowed many features including X.25, electronic mail, fax etc. GSM (Global System for Mobile communication) was developed in 1991, which operated at 900Mhz and uses 124 full-duplex channels. Providers in more than 130 countries have adopted the GSM standard worldwide.

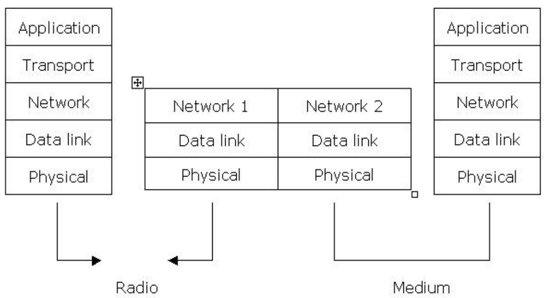

Fig 1: Simplified reference model for mobile communication

It was soon discovered that analog AMPS and digital GSM at 900Mhz were not sufficient to high user density cities. So Europe chose a new frequency band at 1800Mhz. As an effect of this US developed three systems, the analog narrow-band AMPS, the two digital TDMA, and CDMA systems. The GSM-1800Mhz from France had plenty of advantages and was adapted for use in big cities. Nowadays, newer versions of

TDMA, CDMA using spectrum 1900Mhz have also been developed. Many proprietary wireless local area network systems already existed when the ETSI standardized HIPERLAN was developed. There are many types in it with the initial one operating at 5.2Ghz and offer data up to 23.5Mbits/sec and the more recent one operating at 17Ghz up to 155Mbits/sec.

III. A BRIEF INTRODUCTION TO GRID COMPUTING

Definition of a grid: Grids are persistent environments that enable software applied integration of instruments, displays, computational and information resources that are managed by diverse organizations in widespread locations.

Essentially Grid is about resource sharing. There are many computers in the world. They sit in the machine room and connect with each other through the networks. They are even organized together into some organizations or institutions. And they provide some kind of services individually or aggregately. What Grid is trying to do is to build a single computation environment over all the computers and networks. In this environment, applications can have uniform access to all the services in a federated way. In a word, Grid provides a single-machine view of the networked computers. The Grid system is about large-scale resource sharing. Millions of computers can be composed into a Grid. And the Grid system is built on the heterogeneous network. The computers can be of different architectures, different platforms and different network protocols. In the Grid system, the resource sharing relationship is dynamic. It can adapt to the changing in the system. So the large-scale, heterogeneity and the flexibility due to the dynamism are the advantages of Grid computing. However in the Grid model, although the sharing is dynamic, the availability of a single resource is static. Grid assumes the machines are placed in the safe machine room and taken good care of by administrators to provide stable resources. This assumption is challenged by the wireless mobile environment.

IV. OPEN GRID SERVICES ARCHITECTURE (OGSA)

The architecture of a grid or OGSA as defined the Global Grid Forum is as follows,

- Virtual Organization (VO): a set of individuals or institutions that provide or request resources.
- Service orientation: everything is service.
- Service virtualization: definition separated from implementation.
- Service semantics -- the *Grid Service*: standard interfaces of interoperability
  - *Discovery:* service data, service registration, service data retrieving
  - *Dynamic service creation:* service factory
  - *Lifetime management*: service destroy and termination, keep alive
  - *Notification*

V. GUICD-OVERVIEW

A GUICD (Grid-based Ubiquitous Inter-vehicular Communication/Computation Device) is a communication device with finite computational power. It could be visualized as a laptop computer hooked up to a mobile phone. Actually it is more powerful than a mobile phone and less powerful than a laptop computer. It is mounted on a host vehicle. A GUICD consists mainly of two basic components. One is the computing device, which is used to perform calculations about the host vehicle. The other is the communication device, which is used for communication with other GUICDs.

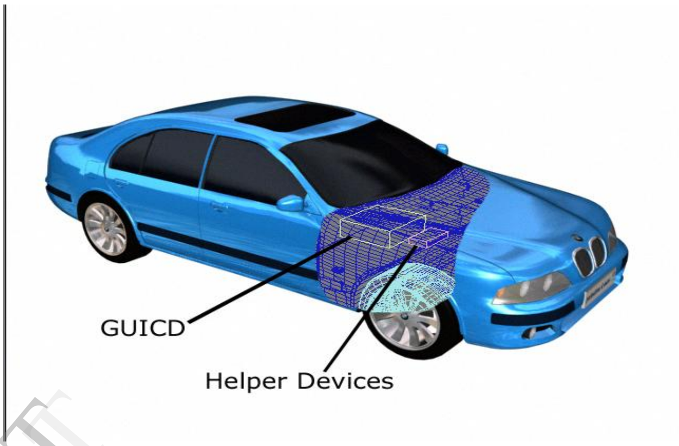

Fig 2: A GUICD in a host vehicle

A basic GUICD's computing device has the ability to calculate the location of the host vehicle and speed at which the host vehicle is traveling. A more powerful GUICD may perform more complex calculations. The GUICD's communication device is the most complex component of the GUICD. The GUICD's communication device can output its own data or get data from other communication devices. But irrespective of the power of the GUICD, the output data is the same. The output contains a header, which is used to identify that it is an output from a GUICD communication device. Besides that it provides the ID of the host vehicle it is plugged into and basic details of the host vehicle such as location, speed, and other information. The GUICD can also read the data object output by other vehicles' GUICDs. The GUICD is integrated into a host vehicle during the time of registration. The vehicle that is being registered is given a registration ID. This registration ID is programmed into the GUICD so that the GUICD of one vehicle cannot be used in another.

VI. TRANSPORT MANAGEMENT SYSTEM ARCHITECTURE

The computing power of a single GUICD is just enough to do basic calculations about the location and speed of the host vehicle. If we find a way to seamlessly integrate all the GUICDs in a given geographic location, we have in our hands a large resource of computing power that is equivalent to that of a powerful supercomputer. Using this virtual supercomputer we can solve a large number of complex problems involved in transport management. The computing power of a single GUICD is just enough to do basic calculations about the location and speed of the host vehicle. If we find a way to seamlessly integrate all the GUICDs in a given geographic location, we have in our hands a large resource of computing power that is equivalent to that of a powerful supercomputer. Using this virtual supercomputer we can solve a large number of complex problems involved in transport management.

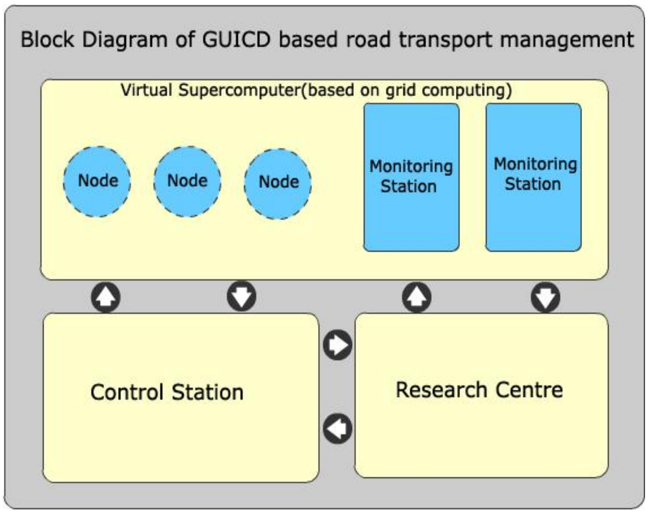

Fig 3: GUICD based road transport management

Many such problems are addressed by algorithms which have already been developed in areas such as internet routing, air traffic control etc.

VII. COMPONENTS

Virtual Supercomputer: Seamless integration of resources to implement our system is provided by grid computing. To introduce grid computing principles into our system, each GUICD's computing device is divided into two parts. One is the local processor, which calculates location and speed and other parameters that are specific to the host vehicle. The other part is the shared processor, which serves as a computing power resource. The shared processor of each GUICD serves as a node of our grid. When these nodes are interconnected using the principles of mobile communication, a virtual supercomputer comes into existence. This supercomputer has enough power to provide real-time transport management.

Control Station: The transport management grid is controlled and managed by various control stations. A control station acts as a person who controls the virtual supercomputer. Each control station may be placed in a different geographic location defined by the amount of traffic density of the area. When a vehicle enters the geographic area defined by a control station it becomes a part of the grid controlled by that control station. When a vehicle crosses over to an area that is controlled by a different control station, then its GUICD automatically becomes a part of the new grid. The control station also controls the traffic lights, railway gates etc.

Monitoring Station: Monitoring stations are provided to monitor the traffic going through a given geographic area. These stations can be provided at traffic control centers. These monitoring stations could be used as a replacement for traffic police booths. Moreover each monitoring station could be provided with a shared processor to keep the system functioning even if the number of vehicles in the system is very low.

Research Station: Research centers can be provided at universities such as the Indian Institute of Road Transport (IIRT). The large amount of real time data provided by our system can be utilized to make improvements to road design, and city planning. These research centers may also be used to refine the algorithms that run on our system. Thus our system becomes evolutionary.

VIII. DRIVER INTERFACE

Efficient traffic control is the most powerful feature of the GUICD system. Traffic jams may occur due to realistic reasons such as narrow road width, poor lighting or road accidents. They may also occur without any reason, which may be explained by cellular automata theory. Our system has the power to prevent traffic jams, which occur due to any of the above stated reasons. Our system accomplishes this task by aiding the driver through its Driver Interface.

The Driver Interface consists of both visual and audio aids. Visual aid is provided by a display unit housed in the vehicle's console. We can warn the driver about approaching traffic congestions, poor visibility areas and other scenarios that may result in traffic jams through warning icons in the display unit.

Directions are given at traffic signals and other places thereby assisting the driver in choosing the optimum path to his destination.

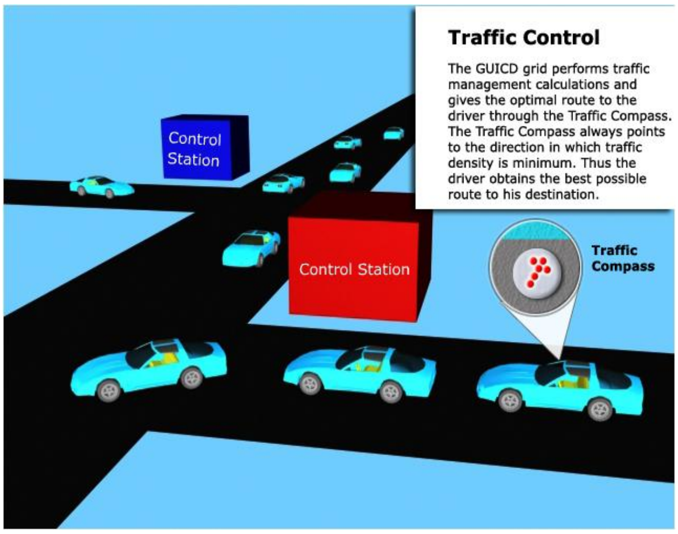

Fig 4: Traffic control using GUICD system

One more alternative is the use of a traffic navigator. The traffic navigator is a device, which is placed inside the vehicle's console and shows a route-map. Audio aid is given by a prerecorded voice which tells about route details like the route with short distance, minimal-traffic routes etc. It also gives warnings about closing of signals, intersection of rails with roads.

The Driver Interface also warns the driver when he/she is on the verge of performing a traffic rule breach like over-speeding, signal jumping etc. In the case of public transport vehicles, consider a bus for example, if the bus driver does not park the bus in the place allotted for it in each bus stop a warning message for incorrect parking is issued.

IX. EXTENDING GUICD

A. Crime prevention:

Crime prevention can be implemented using GUICD system. When a vehicle performs a breach of traffic rules a warning message can be sent to the driver. For example when a vehicle travels at a speed higher than the city speed limit, the monitoring station detects this and sends a warning message to the driver saying that he has crossed the speed limit. A more advanced feature can be added which allows the monitoring station to automatically reduce the speed of the over speeding vehicle to the speed limit. Similarly other crime prevention features can also be implemented.

B. Accident prevention:

Accident prevention can also be implemented using GUICD system. Accidents may occur due to a variety of reasons ranging from blind curves to poor drivers. All these factors, which promote road accidents, can be detected using our system and the right measures can be taken. Our system can inform the driver about blind curves, T-inter section, railway track intersection, speed breakers etc even before the driver visually perceives them. Even if an accident occurs, a message is sent automatically to the nearest hospital to dispatch an ambulance, thus reducing human casualties. Thus due to GUICD system road transport may become as safe as other modes of transport even when long distances are involved.

C. Route finding:

GUICD performs better than a city guide in finding the best route to a destination. This feature can be used with the ease of using a calculator. If we give our destination, our GUICD first connects to the control station nearest to our destination. The route device in our GUICD then obtains the locations of all the vehicles between the current location and the destination. Now the route to our destination is found by tracing the cars between our location and the destination. If we use advanced algorithms we can also find the route, which is the most efficient route in terms if distance and time required. More luxurious vehicles can utilize route finding to add more advanced features such as auto driver. Thus GUICD also acts as an interactive city guide.

X. CONCLUSION

The GUICD system presented here has numerous advantages that it is high time that we implement a system such as this to efficiently manage road transport. Moreover the system presented here can be implemented using currently available technologies and does not need any futuristic technologies though the system itself is futuristic.

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