Smart Traffic Framework Based on Dynamic Mobile Clusters

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Abstract—**With the global trend towards urbanization, traffic control becomes an especially important problem. Existing 'intelligent' traffic control systems are usually of large scale, requiring high computation resources cost, especially equipped roads and traffic lights, and necessary legislations from governments. In this paper, we propose a framework resolves these issues by utilizing the processing power and sensing capabilities of smart devices, as well as relying on constrained optimal global traffic routing, with vehicle speeds, for managing the traffic. The framework constructs on-demand clusters of mobile smart devices, allowing for executing MPI, short-lived, parallel tasks. The tasks are coupled with the on-device sensors thereby decreasing sensed data to tasks communication overheads. The proposed framework requires low-cost coordinating servers, residing on a central cloud, and scales with the mobile devices. Preliminary results are obtained and analyzed based on a number of mobile devices forming a small cluster of heterogeneous mobile nodes. The results confirm the potential scalability of the mobile clusters for a typical optimal traffic control algorithm, and the utility of using standard cluster modeling techniques to predict their performance, making them amenable to standard optimizations.**

Keywords— ***Traffic Control, MPI Mobile Clusters, Intelligent Transportation Systems***

I. INTRODUCTION

With the current trend towards urbanization, it is expected that half of the world population will dwell cities by the year 2050 [1]. The traffic control problem is, generally, one of the significant problems for current mega-cities, and is even further emphasized with such fast urbanization trend.

The state-of-the art in traffic control relies on integrating information technology into traffic systems, referred to as intelligent transportation systems (ITSs). Such systems usually require large costs and time to upgrade the existing traffic infrastructure by integrating sensors and actuators into roads and traffic facilities. Therefore, current ITS system are usually applied in the developed world, and yet on few cities.

With the emergence of the mobile platform, a new form of traffic control has emerged [2-4]. Nowadays, a driver can typically consult his/her mobile application to enquire about road conditions, and decide on a short route. The application relies on the device's GPS and a service provider's server to gather traffic information for the application, from various vehicle users, and construct a corresponding global traffic condition map. Moreover, some other applications rely on crowdsourcing to gather more details about road conditions such as accidents and road works, even providing for clearer routing decisions to drivers [5].

However, currently most mobile traffic systems generally provide information for the drivers without performing actual traffic control. Drivers can indeed avoid traffic bottlenecks, but drivers can possibly create a new bottleneck when they all choose the same route segment is currently uncongested. In other words, there is no global routing or coordination among the vehicles.

With the rapid improvements in the computation capabilities of mobile phones, their high adoption rates, and with the close proximity of vehicles in a city, it becomes possible to exploit such computing and communication power. In this paper, we propose a new computation framework through which vehicles drivers can share their mobile devices and create a dynamic high-performance computing cluster. The cluster provides for 'cheap' computation and filters out communication messages to centralized servers, therefore decreasing the total network bandwidth required, allowing for high system scalability.

A computation cluster is formed on-demand, and supports a light-weight Message Passing Interface (MPI) parallel programming model. The framework provides for managing the creation, termination, and maintenance of the clusters, handling the dynamic nature of clusters, where nodes can drop and join dynamically depending on the vehicles current locations.

In particular, the paper has the following contributions:

- Propose a cost-effective traffic management framework based on smart mobile devices.
- Conduct preliminary framework analysis using a computational intensive traffic control algorithm.

The rest of the paper is organized as follows: Section II presents the framework architecture. Section III describes the traffic control component. Section IV describes the cluster management aspects and the sensing aspects. Section V discusses related work in the literature. Section VI presents and discusses preliminary results. Finally, Section VII concludes the paper.

II. Proposed Framework Architecture

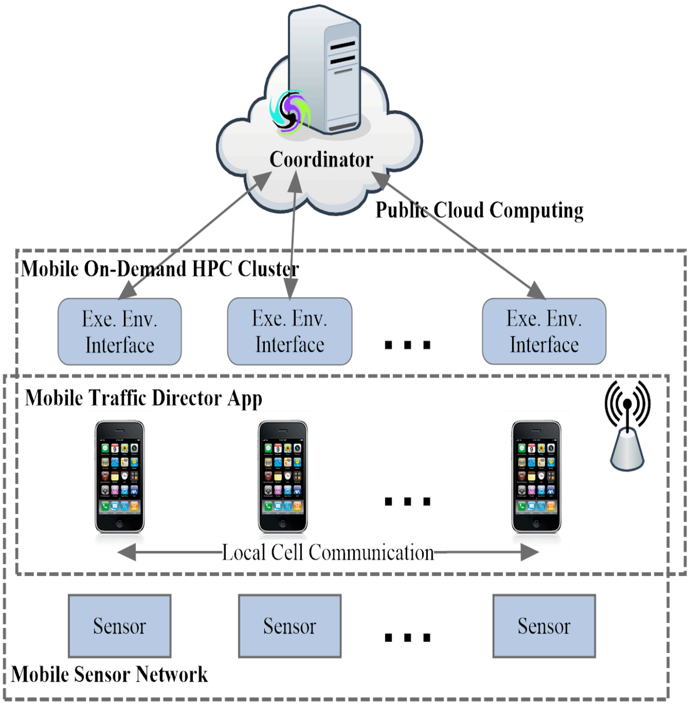

Figure 1 Smart Traffic System Architecture

The framework system architecture consists of four main components, as shown in Figure 1:

- The coordinator: A low-cost server on a public cloud, with the main purpose of coordinating computation on the mobile devices. It is responsible for managing on-demand mobile clusters, gathering processed data, and handling the traffic advisories to the application.
- The mobile cluster: It consists of mobile phones of the drivers on the roads, clustered by the geographical location. The cluster is manifested via an application that provides a standard execution environment interface to the mobile's operating system.
- The mobile sensing network: It is constructed via an application that gathers relevant location information from mobile phones, such as current and historic locations and speeds.
- The mobile traffic director application: It is responsible for presenting traffic guidance information for drivers indicating best traffic routes (routing is done globally for all vehicles).

The framework effectively creates many clusters of spatially located vehicles. With each cluster the vehicles are likely to share the same mobile cellular network thereby the communication would be of a relatively low latency and high bandwidth when compared with general mobile-to-mobile communication. Moreover, currently emerging vehicular ad hoc network can be utilized, providing for even better communication latency and bandwidth. Thus the clusters topology is hierarchical with respect to geo-distances among the mobile devices.

The coordinator can fork large-scale computations across the clusters. A plausible characteristic to exploit is making the decomposition in a data affine manner, where data here refers to the sensed data from the vehicles. Moreover, task interaction can exploit communication hierarchy, accordingly.

The architecture serves as the underlying processing and communication mechanism. On top of that architecture, we require three main software components. The first component is the traffic management component. This includes the traffic controller that performs global traffic routing, as well as traffic simulation. The operation is computationally intensive, requiring efficient utilization of the parallel mobile nodes hierarchy. The second component is the runtime management aspects of the system. This includes cluster management aspects, data storage and various system management issues including coping with faults and the dynamic additions and removals of mobile computing nodes. The third component is the sensor network that senses various traffic aspects such as car speeds and locations, as well as integrating the sensors data into a coherent stream. In the following sections of this paper we describe each component, stating related existing work that may be integrated within the system.

III. The Traffic Mamagnemnt Component

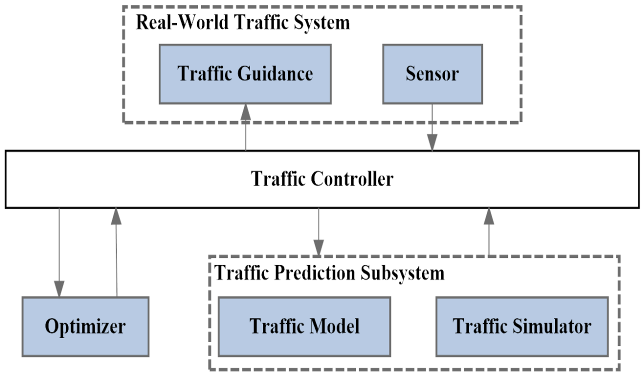

Figure 2 Traffic Management Software Architecture

Obtaining a global optimal solution for routing has the side effect of generating long trips for some vehicle, so as to avoid congestion on short-shared roads [6]. However, Jahn et al. [6] provide a constrained global routing, so as to provide 'fairness' among drivers. An optimal constrained routing is such that any obtained route is within a maximum distance from the user equilibrium route [6]; a user equilibrium route is