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Using Labeled Hyper Multi Digraph for Tabriz Traffic Modeling: Data-Oriented Approach

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Abstract: Traffic congestion has become a major concern in many cities throughout the world, but it is quite difficult to improve the performance of urban traffic efficiently by using traditional methods of modeling because of complexity in the system and Tabriz is not an exception. Modeling the traffic of Tabriz, to develop an intelligent managing system for control the traffic is crucial. Thus, to do so, the concepts of Labeled Hyper Multi Digraph (LHMD) and Labeled Multi Digraph (LMD) as data-oriented models are introduced in this study. This will be the first and essential step to design intelligent transportation systems for controlling Tabriz traffic.

Key words: Data-oriented, digraph, modeling, traffic, transport systems

INTRODUCTION

The main contribution of this study is to introduce a novel, fundamental, theoretical and data-oriented model for traffic modeling of large cities, which is a major concern in modern and large cities, such as Tabriz. In this city, vehicles are part of people's life and always the traffic issue is one of the problems. Therefore, one of the most important aims in this city is minimizing the wasted time on heavy traffic. On average, each person wastes more than 1.5 h on traffic in Tabriz. Totally more than 450,000 L fuel are consuming on traffic every day in this city. In Tabriz, almost 41% of vehicle fuel consumption is wasted on heavy traffic. Controlling of these problems almost is impossible by traditional methods. Therefore, designing Intelligent Transportation Systems (ITS) is essential for these cities. Developing such a system is an attempt to overcome to these kinds of problem including traffic congestion, environmental impact and energy-related issues, by using electronics and telecommunications technology. Modeling traffic is the first step to achieve ITS for such city.

However, modeling the traffic of Tabriz, with population more than 2 millions having more than 2000 junctions and 3000 streets is very challenging. Simple methods of modeling of this city with high performance are essential.

Split, Cycle and Offset Optimization Techniques (SCOOT) (Bretherton *et al.*, 1996) and Sydney

Coordinated Adaptive Traffic System (SCATS) (Sims, 1979) are two notable examples that have been developed and used more recently in many cities and system for priority and optimization of traffic, SPOT, (Kronborg and Davidsson, 2000) has been used in Italy. A traffic model of regular cities with traffic lights using input-output Petri nets with negative multiplicities has built (Farhi *et al.*, 2006). There are some agent-based models at the land use or activities level which enable predictions of future urban patterns but the main focus is at the very micro-level where local movements in terms of traffic are being simulated (Castle and Crooks, 2006).

The main contribution of this study is to introduce a novel theoretical and graph-based model for traffic of Tabriz. This method uses a graph as a data structure. Data-oriented theory presents methods by which any concepts can be modeled in terms of data structures.

The basic structure of data-oriented modeling has been presented by Habibizad-Navin and Mirnia (1999).

Discrete structures like probability digraph, probabilistic language, complete tree walk and n-complete tree walk have been presented for many statistical concepts adaptation with computer. In other words, requirement tools, definition and important mathematical theorems for these models have presented by Habibizad-Navin *et al.* (2005a).

The above methods and structures have been utilized for modeling and then using it for simulating uniform distribution (Habibizad-Navin *et al.*, 2005b).

Data-oriented models of population and sample named classified image have been presented and then provided an algorithm to estimate the distribution of a statistical population based on data-oriented model (Habibizad-Navin *et al.*, 2005c).

New data-oriented modeling of uniform random variables which is well-matched with computing systems has been presented (Habibizad-Navin *et al.*, 2007a).

A data-oriented model of image has been presented (Habibizad-Navin *et al.*, 2007b).

Data-oriented modeling of fuzzy controller for controlling the anti-lock braking system has been introduced (Habibizad-Navin *et al.*, 2007c).

A novel method for improving the uniformity of random number generator named uniformity improving method, or UIM in short, has been introduced and data-oriented model of uniform random variable named UDPD is simulated by this approach (Habibizad-Navin *et al.*, 2007d).

Digital probability hyper digraph for modeling random variables as the hierarchical data-oriented model has been introduced (Habibizad-Navin *et al.*, 2007e).

The basic mathematical discussions about data-oriented modeling of uniform random variables have been introduced (Habibizad-Navin *et al.*, 2008).

The data-oriented model for sine based on chebyshev zeroes has been introduced by Habibizad-Navin *et al.* (2009).

BASIC CONCEPT

Graph is a data structure that shows the connection between members of one set. To outline the new method, some preliminary definitions are provided as follow:

Definition 1: A graph denoted by $G = G(V, E)$ consists of two parts:

- A set $V = V(G)$ consists of vertices or nodes as elements
- A collection of $E = E(G)$ of unordered pairs of distinct vertices called edges (Lipschutz and Lipson, 2000)

Definition 2: A graph $G = G(V, E)$ is a multi graph if and only if E contains multiple edges. Note that any edge connecting the same endpoint implies that E contains one or more loops, i.e., an edge with the same endpoints.

Definition 3: A graph $G = G(V, E)$ is a digraph if and only if each edge in $E = E(G)$ is an ordered pairs.

Definition 4: A graph $G = G(V, E)$ is a labeled graph if its edge and/or vertices are assigned data of one kind or another (Lipschutz and Lipson, 2000).

Definition 5: A graph $G = G(V, E)$ is a hyper graph if and only if at least one member of V be a graph (Habibizad-Navin *et al.*, 2007e). Note that a hyper graph is a generalization of a graph.

Definition 6: A graph $G = G(V, E)$ is Labeled Hyper Multi Digraph (LHMD), if and only if G is a:

- Hyper graph
- Labeled graph
- Multi graph
- Digraph

Definition 7: A graph $G = G(V, E)$ is a Labeled Multi Digraph, LMD, if and only if G is a:

- Labeled graph
- Multi graph
- Digraph

TRAFFIC MODELING

Tabriz, as described earlier, is one of the most important and large cities in Iran. Nowadays, heavy traffic in this city is an important issue. ITS can be used to improve traffic performance by reducing delays of vehicles and the number of times they have to stop. The main contribution of this study is to introduce an LHMD to model Tabriz traffic that can be used by ITS. As shown in Fig. 1, Tabriz divided into four regions such that the boundary of each region is one street. Each street is in a region and one junction can be common to two or more streets.

In a Labeled Hyper Multi Digraph (LHMD) is the direction of the streets. Each node consist many junctions, streets or other nodes.

Figure 2 shows the LHMD model of Tabriz, with three regions. For instance, there exist 16 ways from A to B, but 17 ways from B to A.

To handle this graph electronically, linked list has been used as a data structure. As shown in Fig. 3, the head of the list is the graph G as Tabriz. The regions A, B and C are trailers of G . By considering Tabriz as head and each region A, B and C is linked to it subsequently. Figure 3 shows this method and described with graph in Fig. 2.

By modeling Tabriz as head, each region must be modeled with another LHMD hierarchically. For instance, as shown in Fig. 4, C has been divided into 3 regions.

C can be modeled with LHMD by the same way. Figure 5 shows the LHMD model for C.



Fig. 1: Map of Tabriz with three regions A, B and C

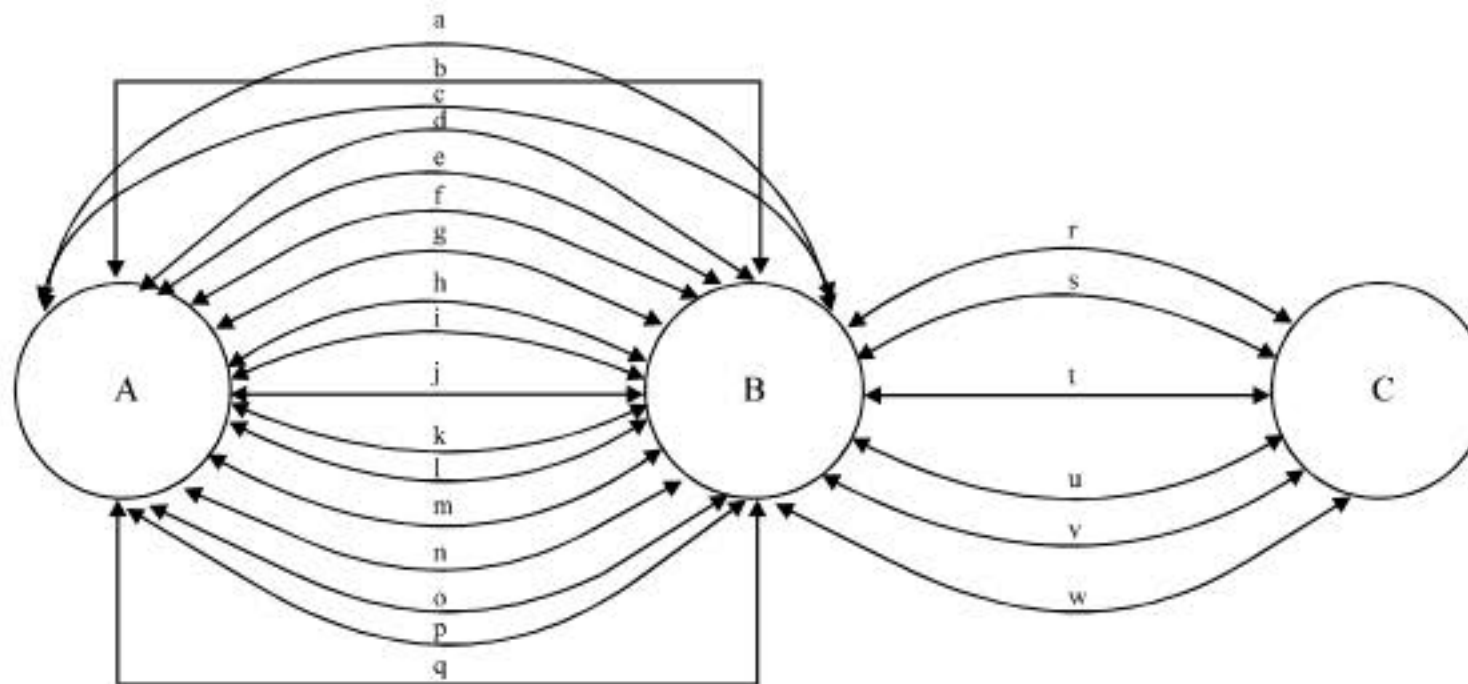


Fig. 2: The LHMD model for top level of Tabriz

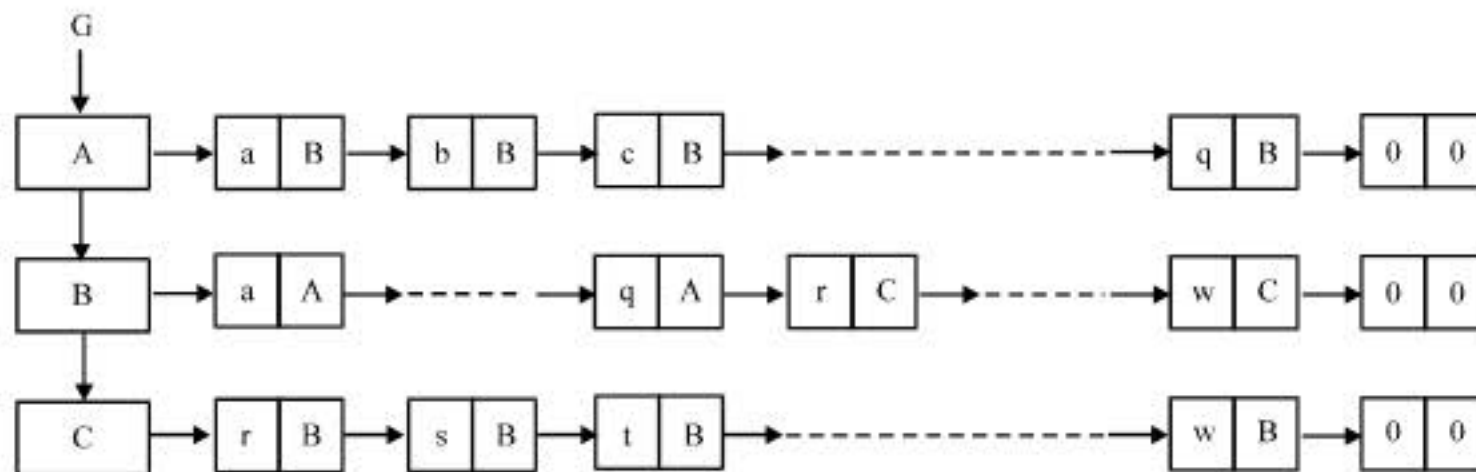


Fig. 3: Considering Tabriz as head with linked list in memory

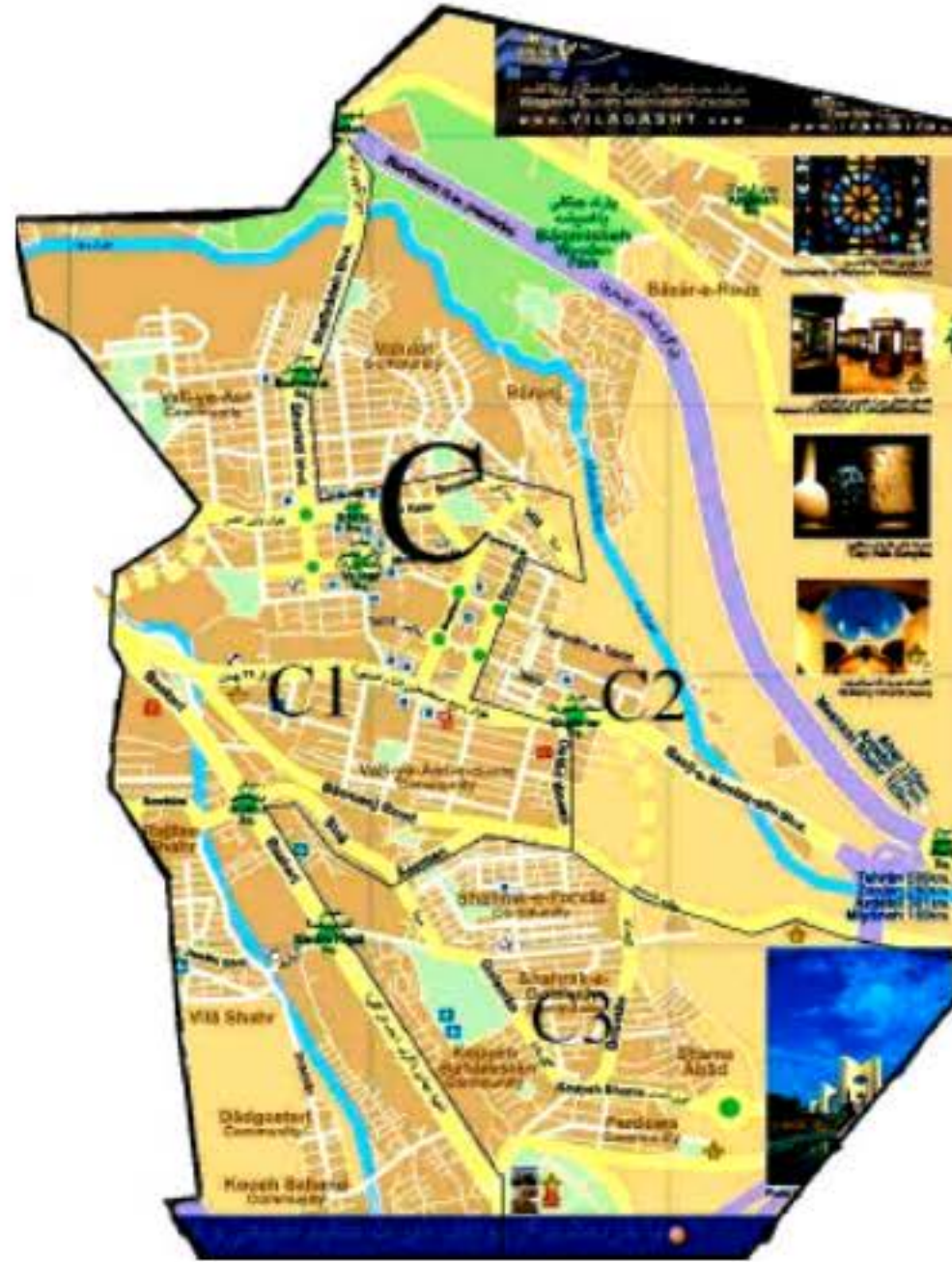


Fig. 4: The region C of Tabriz that is divided into 3 sub regions

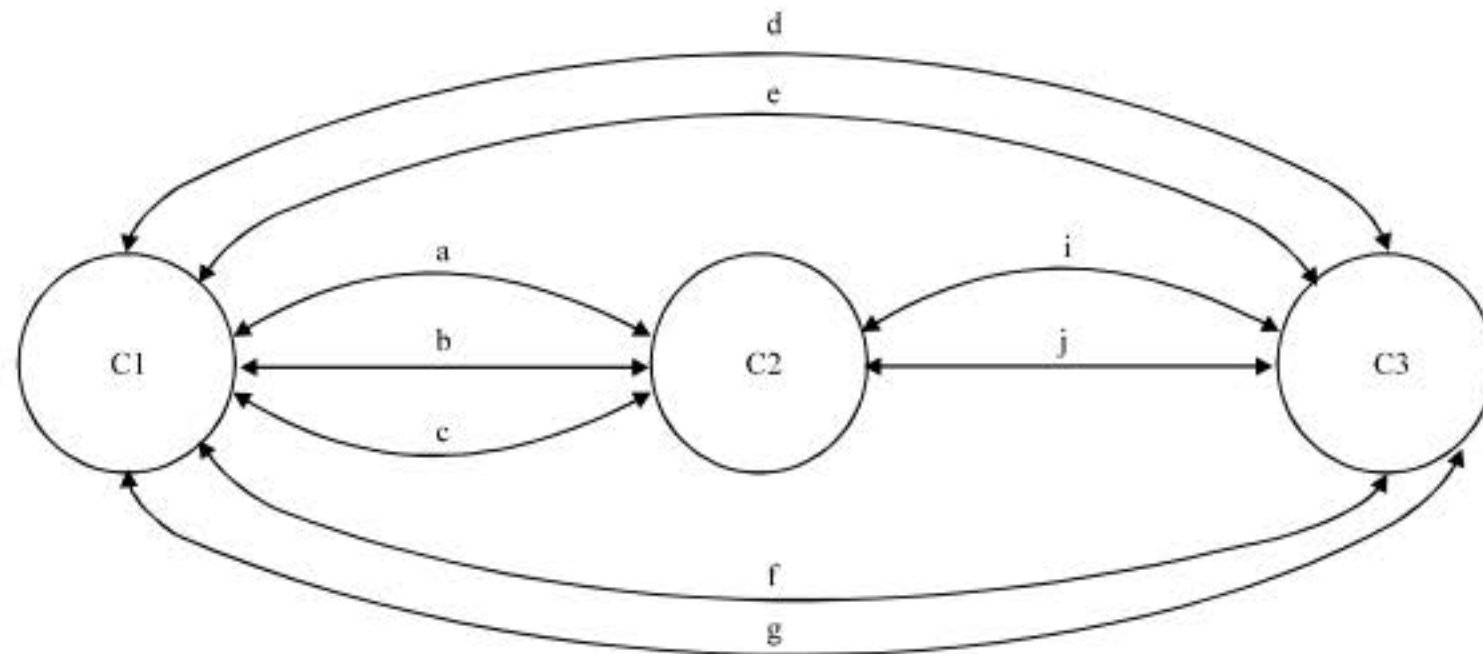


Fig. 5: The LHMD model for C

Figure 6 shows C with linked list as described earlier.

Figure 7 shows the names of the streets and squares. Figure 7 is used for modeling last level of Tabriz. Each node of this LHMD, C1, C2 and C3, must be modeled with LMD because the last level is reached. In the last level each node is one junction and it is not a graph so the hyper graph is not used. Therefore, in the last level of this

method, the LHMD did not used. In this level the LMD graph is appropriate choice. In this method, modeling the traffic of Tabriz or other cities must be done hierarchically with LHMD until the last level.

In the last level of this model, junctions are edges, streets and avenues are vertices and each edge weighted with 2 parameters: the distance between nodes (by meter) and the street width (by number of lines). Therefore, the

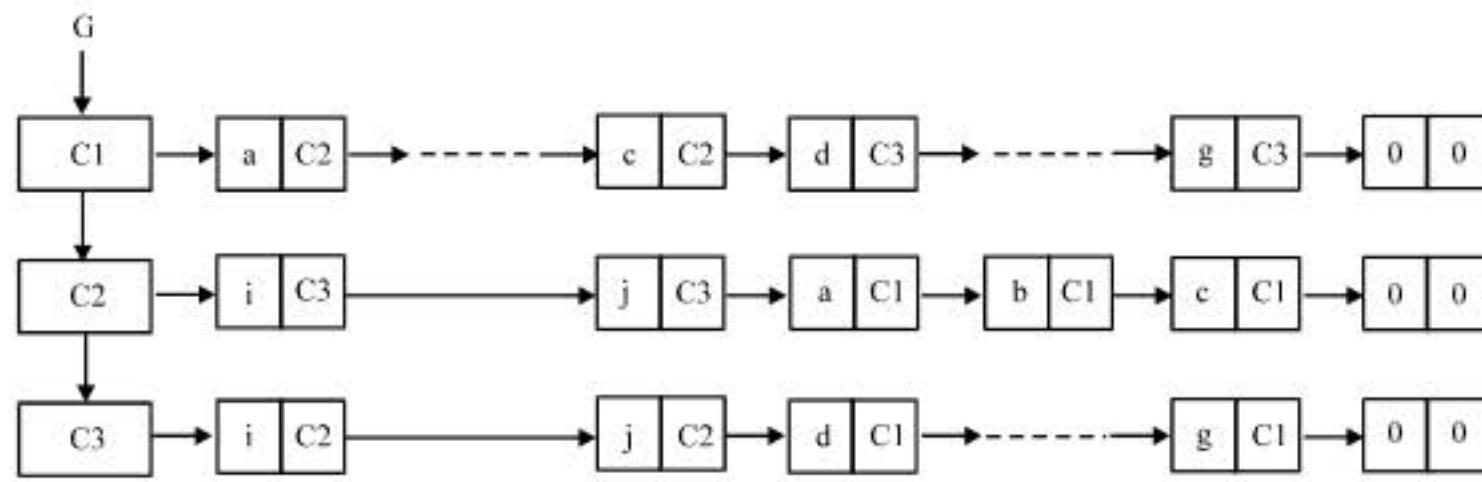


Fig. 6: Maintaining C with linked list in memory



Fig. 7: C3 sub region

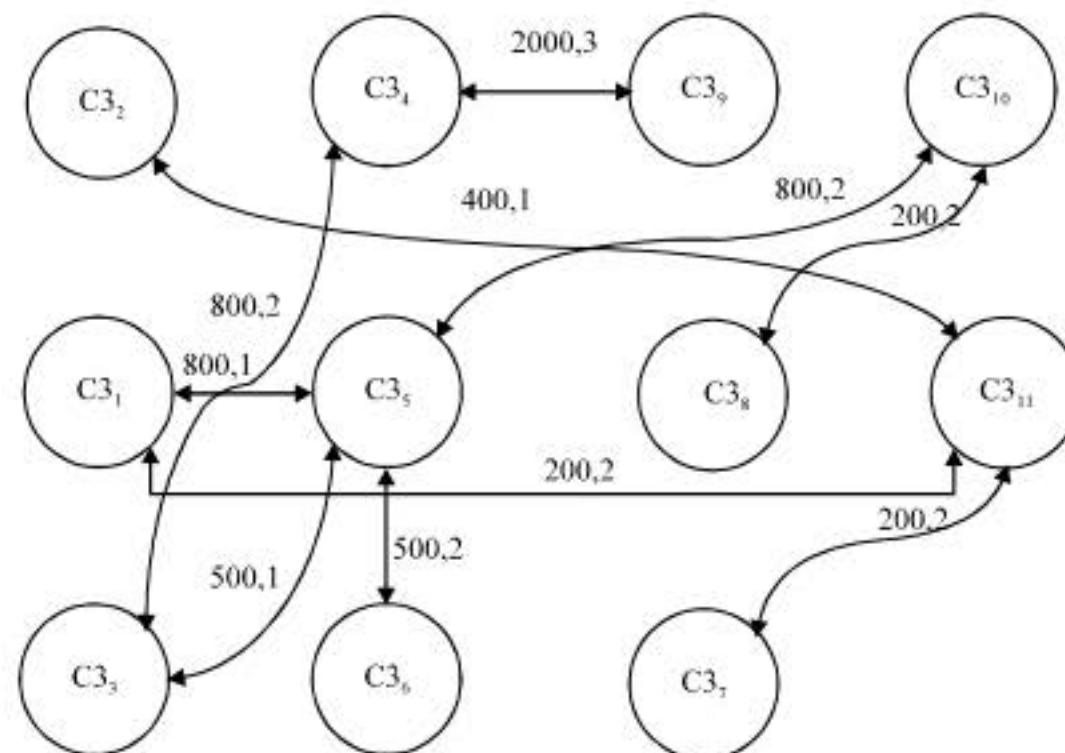


Fig. 8: Graph-based model for C3 with LMD

last level of this model is not an LHMD. The last level must be modeled with Labeled Multi Digraph (LMD). Figure 8 shows this model for C3.

In Fig. 8, C3₂, C3₇ and C3₃ are the common nodes with C1. In C1 all of these nodes exist, because this node is a boundary node and C3₈ and C3₉ are common nodes

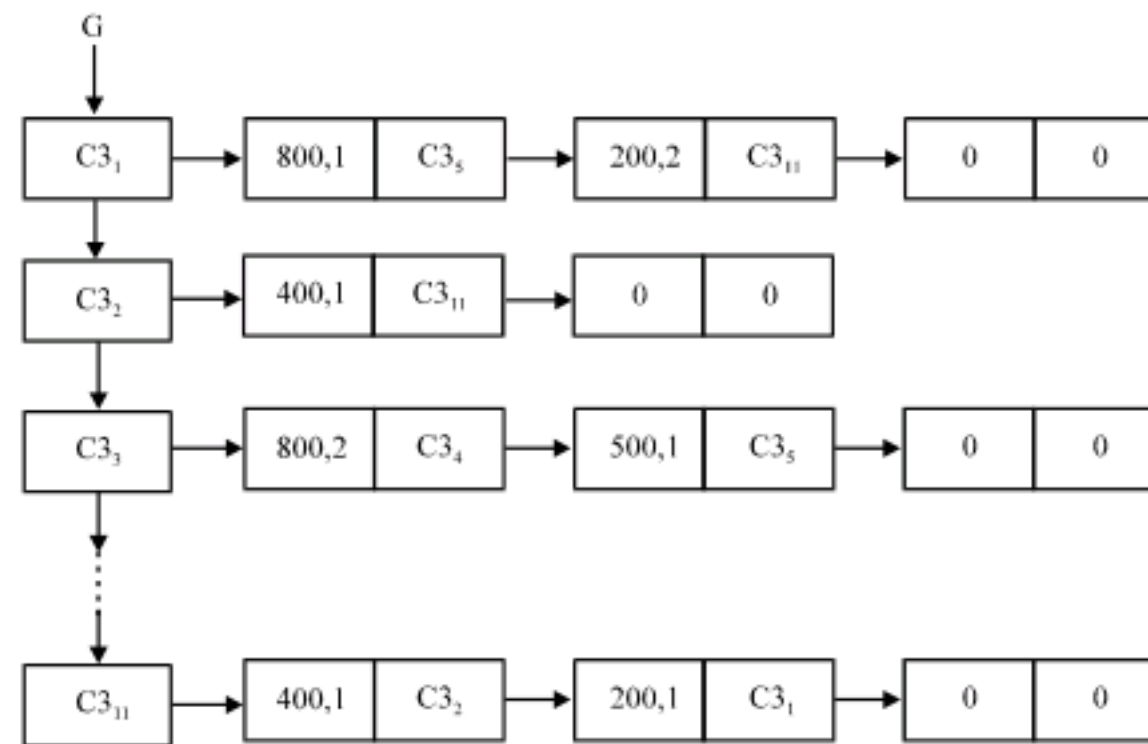


Fig. 9: Maintaining C3 with linked list in memory

with C2. As a previous manner, linked list is used for the last level. For instance, in Fig. 9 this method is shown.

CONCLUSION

Intelligent Transportation Systems (ITS) is essential for the large cities and the first step to obtain an efficient system is modeling the traffic. In this study, new structures, LHMD and LMD are introduced to model the traffic of large cities. Traffic of Tabriz is modeled by these structures and linked list is used for maintaining them in the memory. This model is a data-oriented model of Tabriz, which will use computer to analyze and control the traffic more powerfully and rapidly. This model separated the traffic of Tabriz to three regions and with hierarchically method model the each part of Tabriz. Therefore, this model with less complexity can model the traffic and can used for input of other analytical system. Using this model is useful and essential to achieve an optimized traffic flow or creates green wave. This method improves the traffic performance by using of hierarchically graphs and data-oriented approach. This model is ready and enabled people to create an ITS for Tabriz and also other software and programs can use this model easily.

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