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Traffic Management in 4-way intersection using clique matrix

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***Abstract:** The traffic management problem in four way intersection can be studied using clique graphs. A 4-way intersection with six streams of traffic is considered. The solution of the traffic management problem at this kind of intersection is obtained by using cliques and also signal groups are used for phasing of traffic lights.*

Keywords: **Clique matrix, Traffic management, Traffic streams, Road intersections, Signal Group, Cycle Period.**

I. INTRODUCTION

In urban cities, the major obstacle during peak hours is traffic congestion. Junctions or intersection roads create a conflict between different streams of traffic and require special treatment. Traffic congestion occurs in intersections due to increased vehicular queuing and poor signal control.

When vehicles are totally stopped for periods of time this is termed as traffic jam or traffic snarl –up. Traffic congestion can lead many drivers frustrated and thus engaging them in road rage. Traffic signals are a vital tool used to efficiently and wisely manage vehicle and pedestrian traffic on city roads especially on intersections. The countdown timers at the signalized intersections which assists both the vehicular and pedestrians simultaneously must be managed efficiently to avoid traffic congestion.

In this paper, we have used clique matrix of an undirected graph as a tool to study traffic management problem at a signalized 4-way intersection with six streams including pedestrian streams and shown that usage of clique matrix can be extended for large number of streams.

The paper is organized as follows: In section II we describe the necessary definitions and preliminaries. In sections III, the proposed method has been presented in the form of example. In section IV, signal group phasing and cycle period for the example is explained.

II. PRELIMINARIES AND DEFINITIONS

Road Intersections

The junctions where two or more roads meet are termed as intersections. A three way intersection is a junction between three road segments and a four way intersection represents a crossing over of two streets or roads. Five way intersections exist but are not common. They exist in non-rectangular blocks. Six way intersections is a junction involving crossing of three streets at one junction.

Clique of a Graph

In an undirected graph G= (V,E),a clique is a subset of the vertices V such that every two vertices that are distinct will be adjacent.

Maximum Clique and Maximal Clique

A maximum clique of a graph G is a clique that turns out to be a clique with maximum vertices. In other words the largest clique of a graph is termed as the maximum clique. A maximal clique is always maximal but the converse does not hold.

III. PROBLEM FORMULATION

The traffic control problem which is considered here is 4-way intersection with Six Streams $\rho_1, \rho_2, \rho_3, \rho_4, \rho_5$ and ρ_6 and their directions of movement is also mentioned in the figure1. A compatibility graph as shown in figure 2 is used for modelling the problem such that the streams are represented by vertices and those which can simultaneously move together are joined by edges and those which are in a conflict are not connected by edges. Two pedestrian streams are also used in the problem.

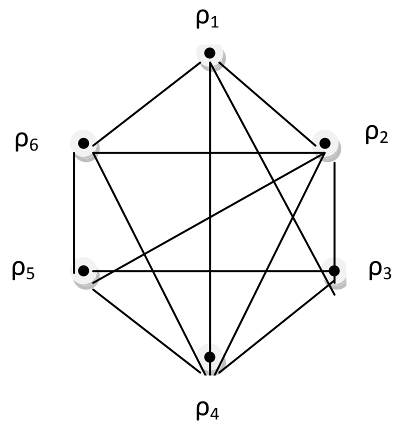

Fig 1: Compatibility Graph

Matrix representation of the graph is much better and convenient for computation. Clique matrix which is basically an incidence matrix is used for this traffic management problem.

The number of cliques formed is:

$C_1 = \{\rho_1, \rho_2, \rho_3\}$

$C_2 = \{\rho_2, \rho_3, \rho_5\}$

$C_3 = \{\rho_2, \rho_4, \rho_5\}$

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$C_4 = \{\rho_2, \rho_5, \rho_6\}$

$C_5 = \{\rho_1, \rho_2, \rho_4\}$

$C_6 = \{\rho_1, \rho_3, \rho_4\}$

$C_7 = \{\rho_1, \rho_2, \rho_6\}$

$C_8 = \{\rho_2, \rho_4, \rho_6\}$

$C_9 = \{\rho_4, \rho_5, \rho_6\}$

$C_{10} = \{\rho_1, \rho_4, \rho_6\}$

The clique matrix represented of the graph in figure 2 is as follows:

$$C = \begin{pmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix}$$

In the above clique matrix,

- In each row, the number of one's denotes the number of cliques formed by the vertex.
- In each column, the number of one's denotes the size of the cliques.

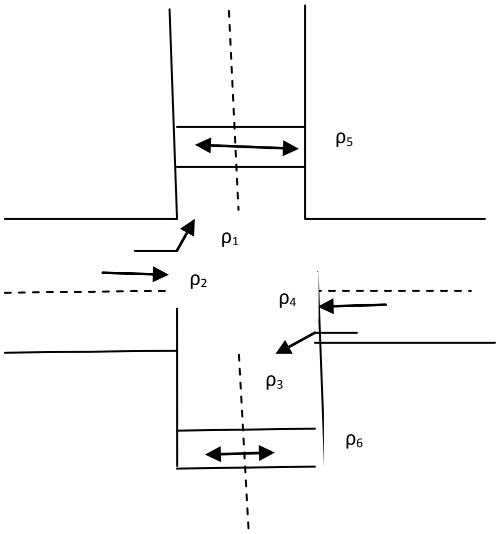

Fig 2: 4-way intersection with 6 traffic streams

Here ten cliques are formed and so signal group phasing and cycle period can be manipulated depending upon the number of solutions. The solution to the traffic control problem is to find the maximum number of traffic streams that can simultaneously move together without any conflicts through the intersection. The solution can be formed from the clique matrix.

IV. SIGNAL GROUP PHASING

The set of traffic streams for which identical indication of signal is provided at an intersection is termed as signal group. From the clique matrix, the traffic streams that are common to most of the cliques can be put in one signal group and signal group phasing can be performed.

Let SG_1, SG_2, SG_3 and SG_4 be the three signal groups on which the ten cliques are put in such that cliques containing the streams that can move together are put in same signal group.

$SG_1 = \{\{\rho_1, \rho_2, \rho_3\}, \{\rho_1, \rho_2, \rho_4\}, \{\rho_1, \rho_3, \rho_4\}\}$

$= \{C_1, C_5, C_6\}$

$SG_2 = \{\{\rho_2, \rho_3, \rho_5\}, \{\rho_2, \rho_4, \rho_5\}\}$

$= \{C_2, C_3\}$

$SG_3 = \{\{\rho_1, \rho_2, \rho_6\}, \{\rho_2, \rho_4, \rho_6\}, \{\rho_1, \rho_4, \rho_6\}\}$

$= \{C_7, C_8, C_{10}\}$

$SG_4 = \{\{\rho_2, \rho_5, \rho_6\}, \{\rho_4, \rho_5, \rho_6\}\}$

$= \{C_4, C_9\}$

Total Cycle Period = 2 minutes or 120 seconds

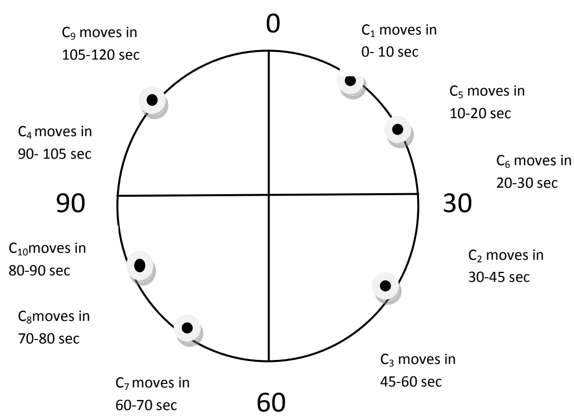

Fig 3: Signal Group Phasing

The cycle period for the streams in C_1, C_5, C_6, C_7, C_8 and C_{10} is 10 seconds each and the cycle period for C_2, C_3, C_4 and C_9 is 15 seconds each.

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The following diagrammatic representation will be more understandable thus making the cycle period 30 seconds for each signal group.

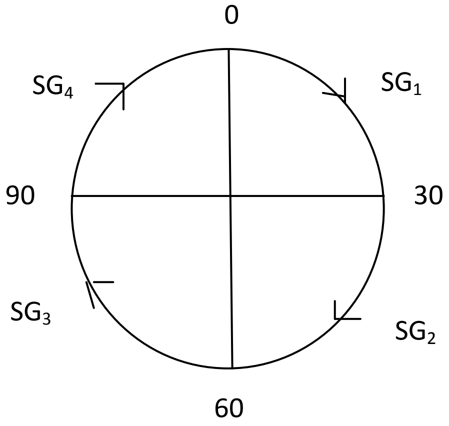

Fig 3: `Modified Signal Group Phasing

V. CONCLUSION

In this paper we have studied a traffic management problem in 4-way intersection using clique graphs. Here we have used a example with six streams including pedestrian streams. This idea can be extended for 5- way and 6- way intersections and also larger number of streams can be considered. Usage of clique graphs and signal group phasing serves as a useful tool for managing traffic at an intersection.

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