

MODELING OF AN ELEVATOR GROUP CONTROL SYSTEM USING PROGRAMMABLE LOGIC CONTROL AND DESTINATION CONTROL SYSTEM

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Abstract. Elevator group control systems (EGCS) have an important effect on the usefulness of buildings, especially for operation of large buildings. The most recent elevator systems have structural differences from the traditional ones, such as Destination Control Systems (DCS), Double-deck elevators, Multi-car elevator system as well as optimization algorithms and modern soft-computing methods. Performance of elevator systems that use DCS is improved given that control strategies can be implemented using the information of destination call before the passenger enters a car. One of the main issues on controlling elevator groups is related to the measurement of traffic intensity in office buildings. Current studies show that passengers flow is often highest in a heavy incoming traffic situation, such as the traffic observed in the early hours of the morning, also known as the up-peak traffic. In order to deal with this demanding situation, the literature indicates the application of some recent developments, among which the concepts of division zone technique, together with the DCS concept, were chosen to be used for the design of the EGCS model described within this paper. Information on call allocation allows special rules to be developed in order to assign an elevator to a sector. This paper proposes a novelty architecture for an elevator system by implementing a control strategy based on fuzzy logic using DCS for a single-car and dynamic-sector approach. The architecture of the elevator group control system was designed in an industrial controller using a DeviceNet® industrial network based instrumentation and the DCS are modeled through human-machine interfaces (HMI) located at each floor.

Keywords: Elevators system, zoning division, destination control, PLC

1. INTRODUCTION

Elevator group control systems EGCS have an important effect on the usefulness of high-rise modern buildings. EGCS are control systems that systematically manage a group of elevators in order to efficiently transport passengers. The elevator system has a dynamic discrete event behavior, in which, the elevator assignment is a multi-objective problem that must be solved in real-time. The scheduling elevator problem is a *NP-hard* computational class and involves a stochastic process, considering uncertainty about the time instant in which a new hall-call button is pressed, about the number of passengers waiting in halls, among others (Beielstein, 2003).

Commonly, the elevator systems performance is measured using the several criteria, such as, service quality related to the waiting time of passengers, traffic throughput and energy consumption (Beielstein, 2003).

Conventional EGCS implementations are based on fuzzy logic, neural networks, genetic algorithms, Markov chains, among others (Kim, 1998), (Liu, 2007), (Ikeda, 2008), (Nikovski, 2004). Previous works covering EGCS implementation for scheduling the elevators are focused on several aspects, such as, static zoning division and dynamic zoning division strategies. In the static zone approach the floors are divided in static zones (Barney, 1985), (So, 2001). Usually the number of zones is equal to the number of elevators. In the dynamic zoning approach, each elevator has a service zone which changes according to the position and movement direction of the elevators, in order to balance the elevators state between busy and idle (Yang, 2007).

In a traditional elevator control system, up and down hall-call buttons are used. The latest elevator system has structural differences from conventional systems, such as, Destination Control Systems (DCS) that allows to know the desired floor before the user enters in a car (Markon, 2008). Performance of elevator systems that use DCS is improved given that control strategies can be implemented by using the previous information about the number of passengers waiting for a car, as well as, the destination call of the passengers. The DCS provides more accurate information; therefore, the control system can group passengers going to the same floor in the same car, reducing the waiting time and the number of stops due to the destination calls is reduced (Sorsa, 2005).

This paper proposes a Fuzzy Elevator Group Control System (FEGCS) that selects the most suitable elevator for attending a hall-call and identify traffic patterns in the building. We focus the control strategy by using a dynamic zone division according to the current traffic condition in the building. The FEGCS receives as input parameters the information sent by the Destination Control System (DCS). Also, this paper describes a novelty architecture for an elevator system, using a PC for implementing the FEGCS, a Programmable Logic Controller (PLCs) for performing the Local Control Systems (LCSs) and industrial instrumentation, such as, a DeviceNet industrial network and some Panel

View for implementing the DCSs. This architecture allows the elevator system to benefit of the advantage proportioned by industrial automation, highest safety and integration with the others systems in modern buildings.

2. ELEVATOR SYSTEM

The elevator group system is a control system that manages systematically three or more elevators in a group to increase the service of passengers, reducing the waiting time and the power consumption. Most of the elevator group control systems (EGCS) have used the hall call assignment method which assigns elevators in response to passenger's calls. In this case, the elevator group control system considers the current traffic situation of a building to select the most appropriate elevator (Kim, 1995).

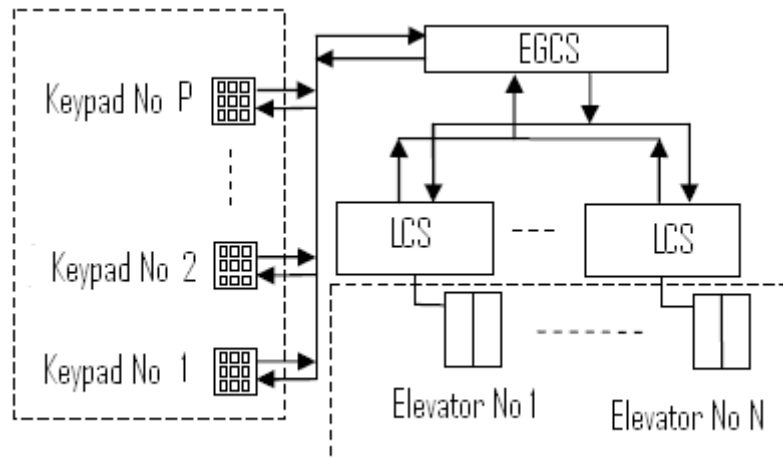


Figure 1. Elevator system (Tai, 2008).

Figure 1 shows a conventional elevator system using Destination Control Systems (DCS), one per floor. It can be observed several Local Control System (LCS), one per elevator. Each LCS receives as inputs the commands sent by the EGCS and control the traction engine of the respective elevator. Also the LCS performs the security rules in the shaft. The LCSs are connected to the EGCS through a communication network, as well as, the DCSs are connected to the EGCS in order to send the following commands: (1) current floor from which a new hall-call is performed. (2) Destination floor of the new hall-call. The use of DCSs allows the controller to know previous information before the user enter into a car.

A Programmable Logic Controller (PLC) is an industrial computer used for automation. PLCs are used in many process industries and machines, such as packaging, manufacturing processes, semiconductor machines, among others. The PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. A PLC is an example of a real time system since output results must be produced in response to input conditions within a bounded time. The PLCs includes different communication protocols that may be used such as DeviceNet or Profibus (Erickson, 1996), (Schiffer, 2000).

3. RELATED WORK

Many studies have been proposed in order to implement different control strategies for ElevatorGroup Control System (EGCS), improving the performance in different traffics situations. Conventional EGCS implementations area based on fuzzy logic, neural networks, genetic algorithms, Markov chains, among others (Kim, 1998), (Liu, 2007), (Ikeda, 2008), (Nikovski, 2004).

Kim et al. (Kim, 1998) implements an Elevator Group Control Systems (EGCS) and propose a control strategy generation method based on a Fuzzy Elevator Group Control System (FEGCS) for the hall-call assignment. The control strategy of the FEGCS is performed using a classification of traffic and a dispatcher manager for assigning the hall-calls to suitable elevators. The system works using the given control strategy which is defined by the system manager. In Siikonen (Siikonen, 1997) a FEGCS is proposed for implementing a forecasting method and a fuzzy system for traffic patterns recognition. Also, in this FEGCS the next floor to be visited by the car is calculated using a cost function, taking into account the current traffic situation in the building.

Control approaches using different kind of zoning division was proposed in Barney (1985). (Barney, 1995) propose an algorithm of static sectoring and dynamic sectoring. Static sectoring uses a control algorithm to detect when the up traffic from the terminal floor exceeds a pre-determined level. This situation could be present when the number of passengers waiting for a car threatens to overload the lift system capacity. The algorithm will assign each car to serve

a particular building zone. Dynamic sectoring uses the same protocol as static, but includes a feedback algorithm, which allows the sectoring to vary from trip to trip according to the traffic demand (Russett, 2003).

Recently, new models of elevator group intelligent system with Destination Control System (DCS) have been proposed by Suying Yang et al (Yang, 2009). It studies a dynamic partition method in up-peak. This method perform a dynamically adjust division of floor region based on flow rate and distribution of passengers. Also a dynamic programming algorithm is used to solve this problem and a Fuzzy Neural Network is developed applying in order to realize the optimal scheduling policy.

In general, approaches using DCS allows to increase the handling capacity in up-peak traffic situations. In previous works the waiting time of passengers has been decreased, obtaining better performance than approaches using heuristic control rules (Tai, 2008).

Nowadays, the elevator system should allow to leads, at the same time, complex algorithms for performing the dispatcher of the elevators in an efficient way and robustness systems that provides functionality for implementing the different control strategies and reliability, security in the data transmission. Therefore, implementations using Programmable Logic Controller (PLC) could be an important advance in the elevator systems development.

(Yang, 2008) describes an architecture involving only one PLC for performing an elevator system with two elevators and nine floors; however, there is not a group controller. This fact difficult the scalability of the elevator systems. In the other hand, the work presented by Yang, (2008) does not consider the use of DCS, avoiding to perform suitable control strategies for heavy traffic situations. Architectures using PLCs and DCSs have been currently implemented by Thyssenkrupp. (Thyssenkrupp, 1999) proposes an architecture based on PLCs and a CAN bus network ensuring reliable connection of all components. The architecture proposed in (Thyssenkrupp, 1999) considers the use of one PLC for implementing the LCS of each elevator. However, the algorithms involved in the LCSs does not need complex computations; therefore, could be an interesting approach to implement as many as possible LCSs in the same PLC.

4. DESCRIPTION OF THE PROPOSED ARCHITECTURE

The architecture of the proposed elevator system is shown in Fig. 2. This architecture consist in elevator group controller running on PC, a Programmable Logic Controller (PLC) for implementing the Local Control Systems (LCSs) and a DeviceNet® industrial network for connecting several instrumentations such as frequency inverters, inductive sensors and PanelView devices for implementing the Destination Control Systems (DCSs).

The elevator group controller was designed using the division zoning technique and a Fuzzy Elevator Group Control System (FEGCS) for computing the suitable value of each elevator in order to attend a hall-call. The suitable value is computed taking into account standard criteria of performance, such as, waiting time of passengers, loading capacity of the elevators and distance (in number of floors) between the hall-call and the destination call. The elevator group controller also implements a fuzzy system for identifying traffic patterns in office buildings.

The elevator group controller was developed in Java language and receives the decisions from the FEGCS in order to selects the elevator with the most suitable value for attending a new hall-call and performs the zoning division taking into account the current traffic situation in the building.

As shown in Fig. 2 the proposed architecture considers only a PLC for implementing several Local Control Systems, taking advantage of the versatility and robustness of industrial devices. This fact allows to implements basic algorithms for controlling the motor engine, open/close door, among others. Also the LCS receives information from the inductive sensors in each shaft in order to positioning the elevator. A DeviceNet® industrial network is proposed for connecting the PLC with the industrial devices, such as, some frequency inverters (each for one elevator), the inductive sensors in the shaft and the PanelView (each for one floor) which implements the DCSs.

The communication between the PLC and the group controller was accomplished by a client-server Java application called OLE for Process Control OPC (1996). OPC allows a standard for real-time information exchange between software applications and hardware processes.

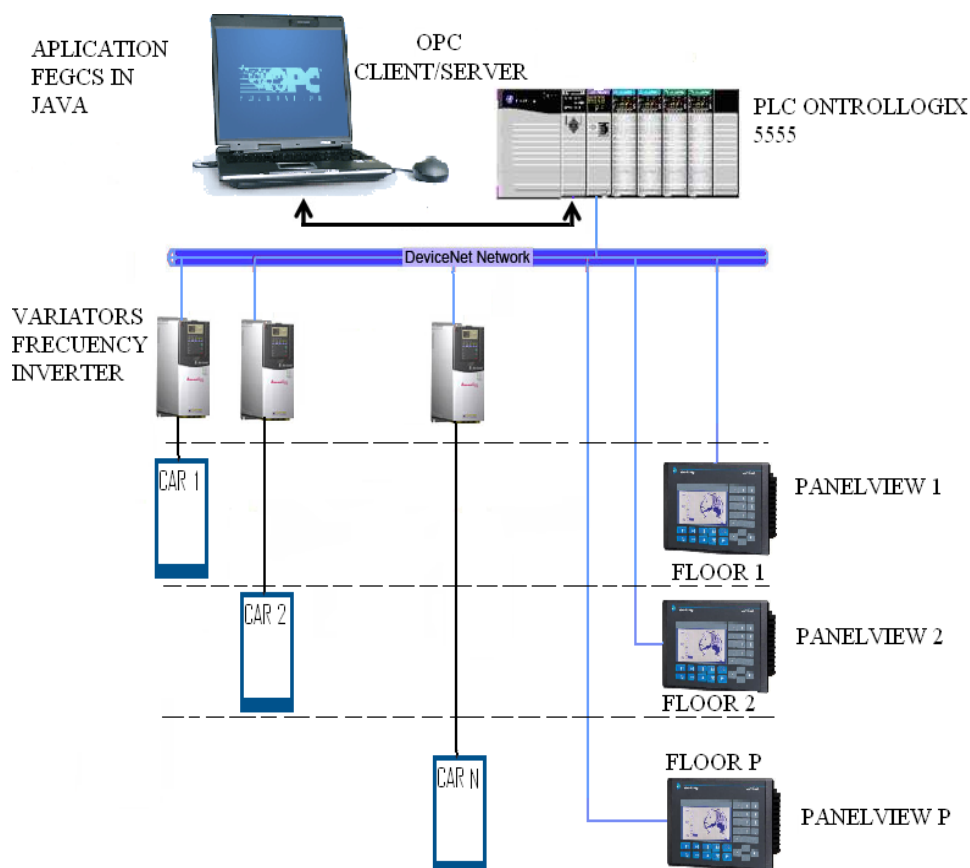


Figure 2. Architecture of the elevator system.

4.1 The zoning division technique

In this work, the division zoning technique is used for adapting the group controller of the elevators to the traffic conditions in the building. Therefore, this technique takes into account the traffic patterns identified by the FEGCS. This traffic patterns have different characteristics and can be founded at different time in office buildings. Table 1 describes the characteristics of traffic patterns used in this work and the proposed zoning division for each one of them. In this work we use the division sectoring system proposed by Barney (2003), in which the number of division zones corresponds to the number of elevators in the building and each elevator is allocated to only one zone, attending the corresponding hall-calls in a collective approach.

Table 1. Traffic patterns and zoning division.

Traffic Patterns	Description	Zoning Division
UP (Up Peak)	A lot of passengers come into a building.	The first floor (lobby) is assigned to a zone. The remaining floors are divided in symmetric zones (same number of floors).
BT (Business Time)	Interfloor calls. Total traffic is medium and small.	Symmetric zones. When an elevator remains inactive for more than 5 seconds, its status is declared as free and goes to the boundary between adjacent zones, being available in the up or down direction.
DP (Down Peak)	A lot of passengers going out from the building.	Symmetric zones.
HT (Heavy Traffic)	Many passengers gather into a floor. Up, down and interfloor calls. Total traffic is high.	In this case an algorithm was implemented for dividing the zones according to centralized floors. The floor with more than 50% of centralized traffic is assigned to a zone and the remaining floors are divided in symmetric zones.

4.2 The traffic identifier

Figure 3 shows the structure of the traffic system identification. This system is based on fuzzy logic and was developed using the Xfuzzy tool (Xfuzzy 3.0, 2003). This system receives as input four traffic characteristics and returns the current traffic pattern in the building, choosing one among four traffic patterns (see Tab. 1). The traffic identifier is periodically executed (commonly every 15 minutes); therefore, the traffic characteristics must be computed in the same interval of time meaning a numerical value of the intensity of traffic. Table 2 describes the four traffic characteristics used in this work. The number of up hall-call, down hall-calls and number of passengers waiting in the halls can be computed by using the information provided by the PanelView (see Fig. 2).

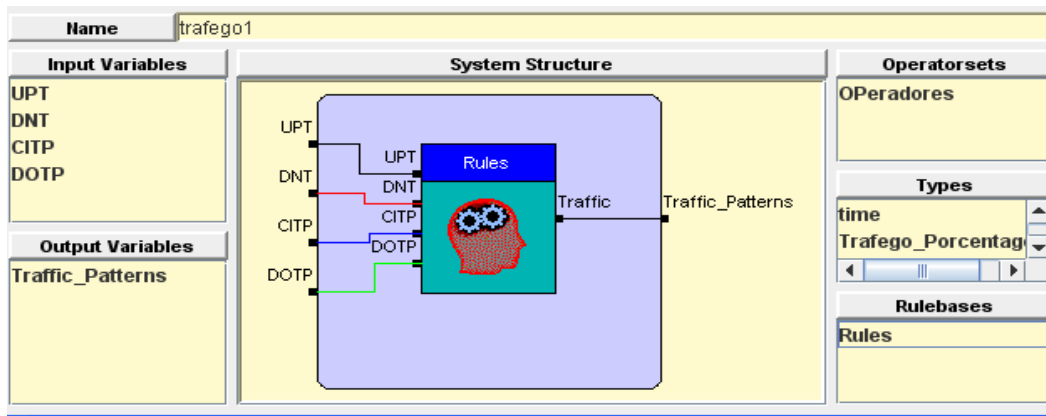


Figure 3. Fuzzy traffic identifier

Table 2. Input variables for zoning division.

UPT (UP Traffic)	Number of up going passengers
DNT (Down Traffic)	Number of down going passengers
CITP (Centralized Incoming Traffic Percentage)	Percentage values of the ratio of the incoming passengers in the most crowded floor to that of all floors.
DOTP (Distributed Outgoing Traffic Percentage)	Percentage value of the ratio of the out-going passengers in all floors except the most crowded floor to that of all floors.

4.3 The priority calculation

When a new hall-call is requested, a fuzzy system is executed in order to compute the priority value of each elevator for attending this hall-call. This computation must be performed N times, where N is the number of elevators, in order to find the most suitable elevator. Figure 4 shows the structure of the fuzzy system that computes the priority value of one elevator.

The priority calculation fuzzy system receives as input three important variables of the performance measurement of elevator systems, they are:

- Distance: is the number of floors that the elevator must be perform from the current position of the elevator to the floor where the new hall-call occurred.
- Loading car. The loading of the car is the current number of vacancies available in the car when it arrives at the floor from where the hall-call occurred.
- Waiting time: is the estimated time that the passengers must wait in the halls until the elevator arrives at the floor after the passenger presses a new hall-call button. The estimated waiting time is computed as equation (1).

$$\text{Waiting Time} = (\text{Stop Number}) \times T_v + (\text{Distance}) \times T_s \quad (1)$$

Where,

T_v = Door opening time + Door closing time.

T_s = Time to transit two adjacent floors at rated speed.

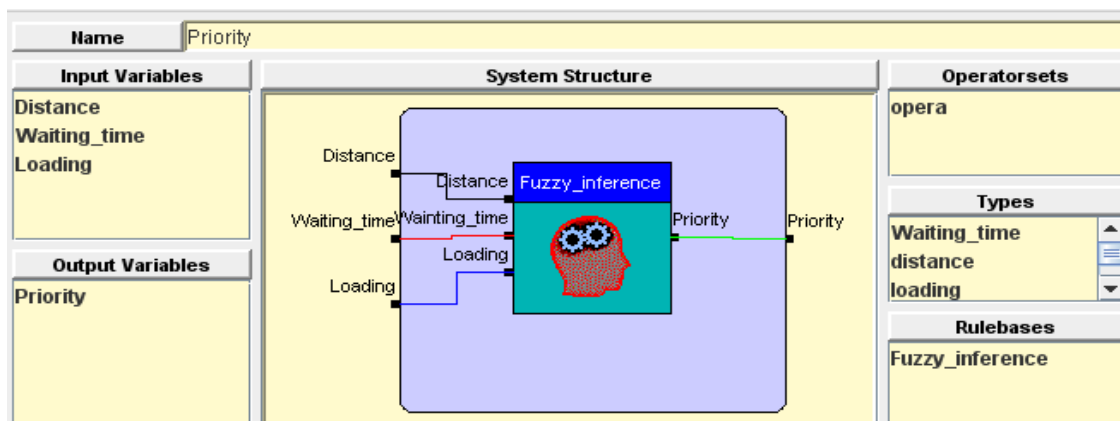


Figure 4. Fuzzy priority calculation

4.4 The main algorithm

This algorithm controls elevator system by using a zoning division approach and Fuzzy Elevator Group Control System (FEGCS) for computing the priority value of the elevators and traffic patterns identification. The zoning division approach considers that the number of division zones corresponds to the number of elevators in the building, and then, each elevator is allocated to only one zone, attending the corresponding hall-calls. When an elevator is currently assigned to a zone, this zone is called an occupied zone. In the other hand, when a zone has not an elevator assigned, it is called an empty zone.

Figure 5 describes the flowchart of the main algorithm which is performed when a new hall-call is requested. This algorithm consists of five stages. At the first stage the algorithm has a current zoning division, which is setting-up by the fuzzy traffic identifier (see section 4.2). At the second stage the algorithm performs several decision operations in order to determine if this zone is considered an empty zone. These decision operations ask about the occupation of the zone from which the new hall-call was requested, about the direction of the elevator with respect the hall-call direction and about the loading capacity of the elevator (in case of an elevator to be currently assigned to this zone).

When the zone is empty the algorithm executes the third stage, otherwise executes the fourth stage. The third stage active the fuzzy priority calculation (see Fig 4) in order to select the most suitable elevator for attending the hall-call requested. Finally, at the fourth stage the state of the current zone is considered occupied, and then the algorithm performs the dispatcher of the elevator by using the collective principle until the elevator leaves this zone, being declared as an empty zone.

4.5 The communication protocol

The communication between the FEGCS and the PLC is a client-server application was accomplished in Java language. This communication is performed through an OLE for Process Control (OPC) which is an open communication protocol widely used in industrial automation and enterprise systems, given that OPC provides high versatility of industrial automation. The OPC protocol runs in a PC (Personal Computer) and was implemented in the same main group controlling algorithm, as shown in Fig. 5.

The server-OPC protocol allows the group controller to interchange data with the PLC. This data are based on state variables and action commands. The state variables indicate the current state of each elevator and action commands indicate the decision making by the main algorithm that must be executed by the elevators in order to improve the performance of the overall system. In the client-OPC is implemented the main algorithm and allows through a socket to shares data with other applications, such as, supervisory system and simulation environments.

A DeviceNet® industrial network is proposed for connecting the PLC with the industrial devices, such as, some frequency inverters (each for one elevator), the inductive sensors in the shaft and the PanelView (each for one floor) which implements the DCSs.

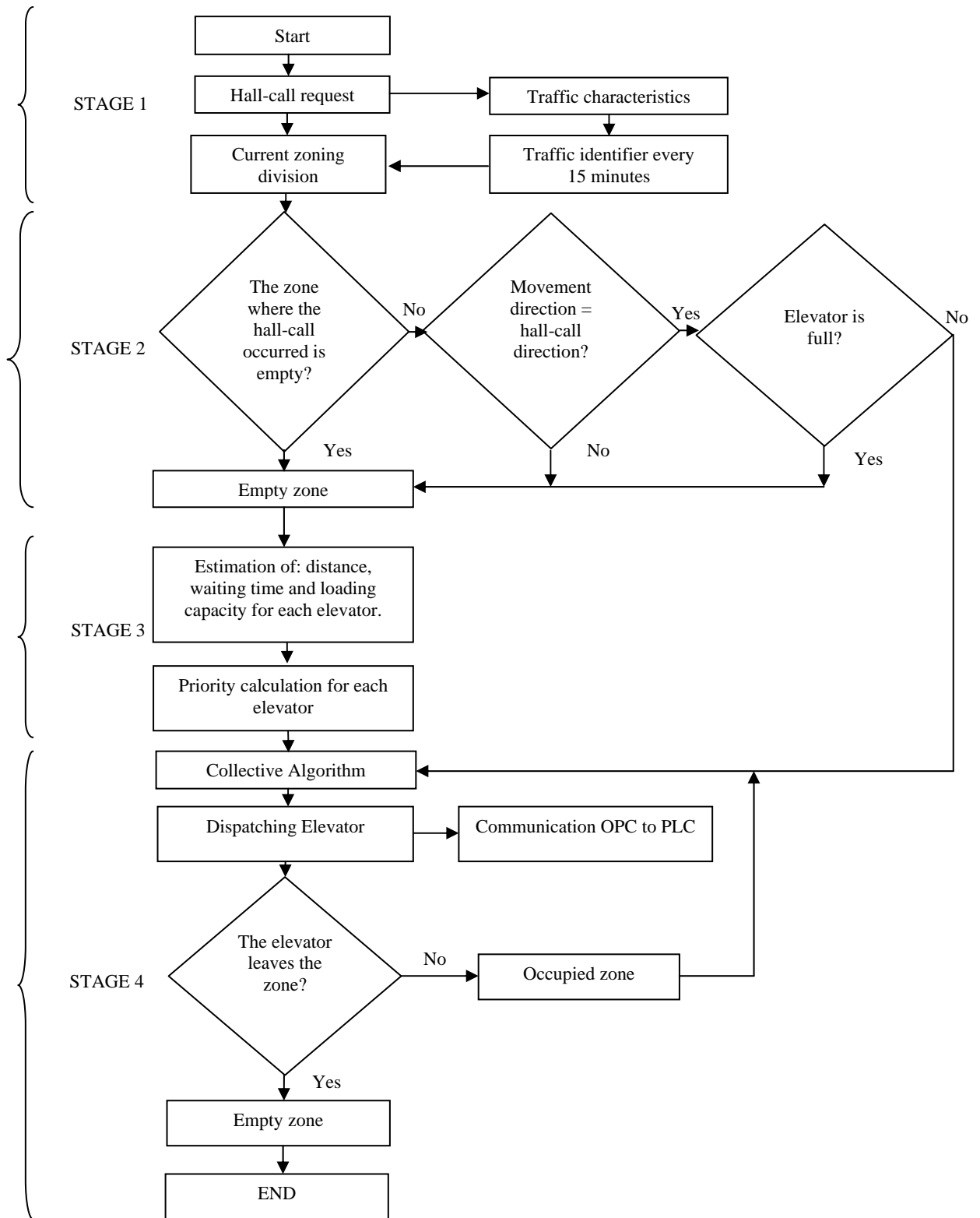


Figure 5. A flowchart of the main algorithm

5. CONCLUSIONS

This paper has proposed a novelty architecture for elevator systems based on a DeviceNet® industrial network for connecting several industrial devices, such as, a Programmable Logic Controller (PLC) which implements the Local Control Systems (LCSs), Panel View for implementing Destination Control System (DCS), frequency inverters and inductive sensors. The OLE for Process Control (OPC) was developed in Java language sending data between the PLC and a Elevator Group Control System (EGCS) based on fuzzy logic (FEGCS) and division zoning techniques that runs on PC.

The EGCS was designed to increase the performance of the system of elevators and takes advantages of the division zoning techniques and the traffic patterns identification performed by FEGCS, as well as, the pervious information provided by DCS, avoiding uncertainties of conventional system.

The LCS was designed to be implemented in only a single PLC, saving industrial instrumentation, decreasing energy consumption and implementation cost. By accomplishing the proposed architecture we hope that the elevator system takes advantage such as, security, versatility and robustness provided by industrial instrumentation. The DeviceNet® industrial network allows connecting up to 64 nodes increasing the scalability of the system in terms of number of elevators and number of floors. The use of OPC protocol provides high versatility and flexibility in the transmission of the information, allowing to explorer new approaches for controlling automation integrated system in modern buildings.

As future works we pretend to explore the capabilities of the PLC for implementing elevator control system, as well as, to develop a simulation environment in order to validate the proposed architecture.

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