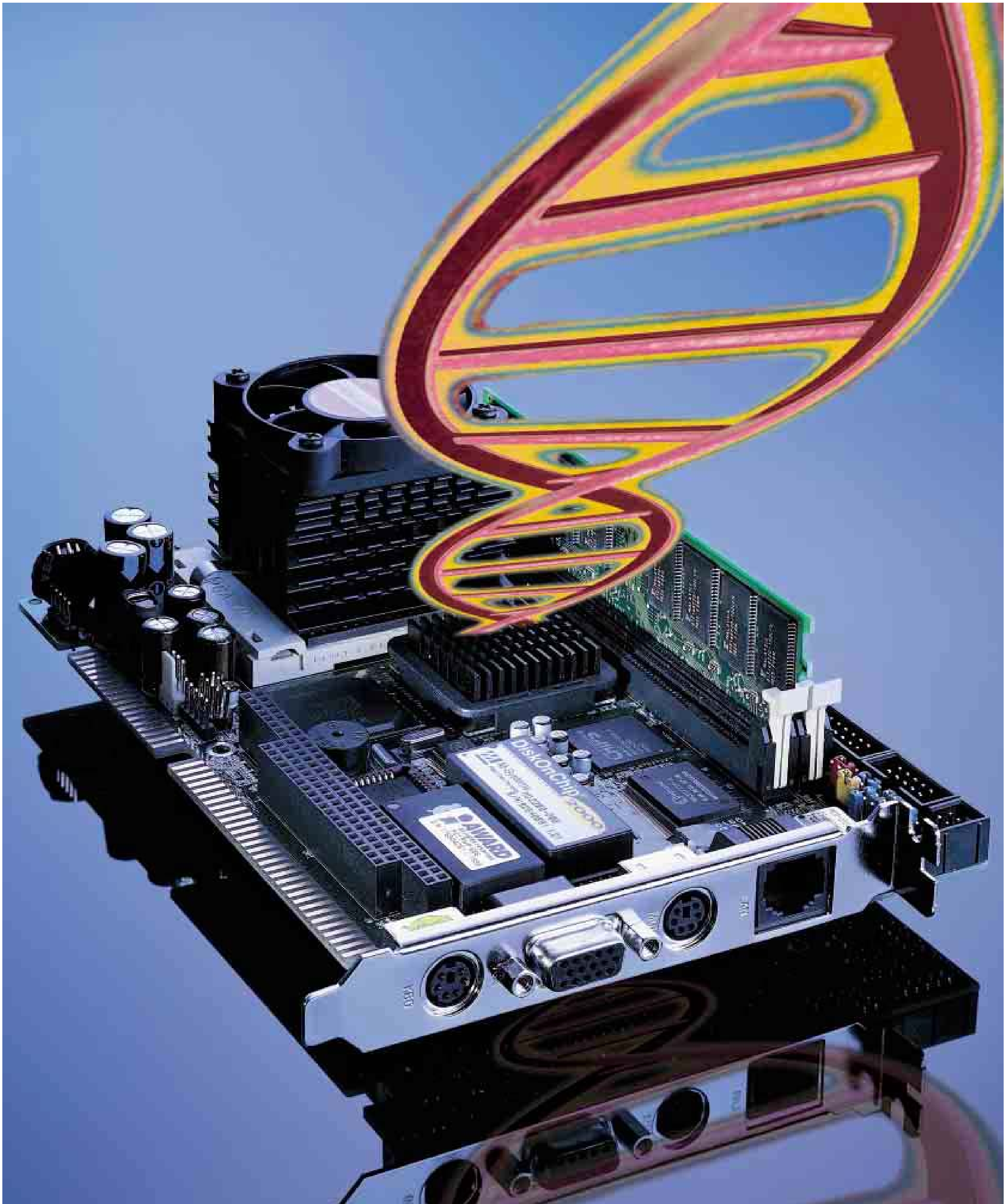
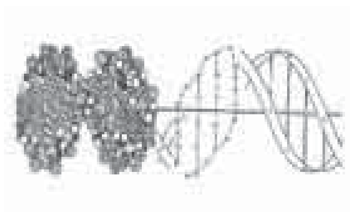
KONE TMS9900 GA Group Control System

Fact Sheet



KONE TMS9900 GA

With genetic call allocation algorithm



The control system with the best genes

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CALL ALLOCATION ARCHITECTURE

Fig.1 shows a block diagram of the TMS 9900 GA call allocation algorithm

Elevator and hall call data are processed prior to their use by the algorithm, including the statistical forecasts of the passenger traffic.

Genetic Algorithm searches the optimum routes for the elevators to serve the active landing calls. The algorithm identifies the best routes for the elevators by imitating evolution in a computer in the same way as it takes place in nature. Stable and optimal call allocation decisions are guaranteed by using measured elevator stopping times and flight times.

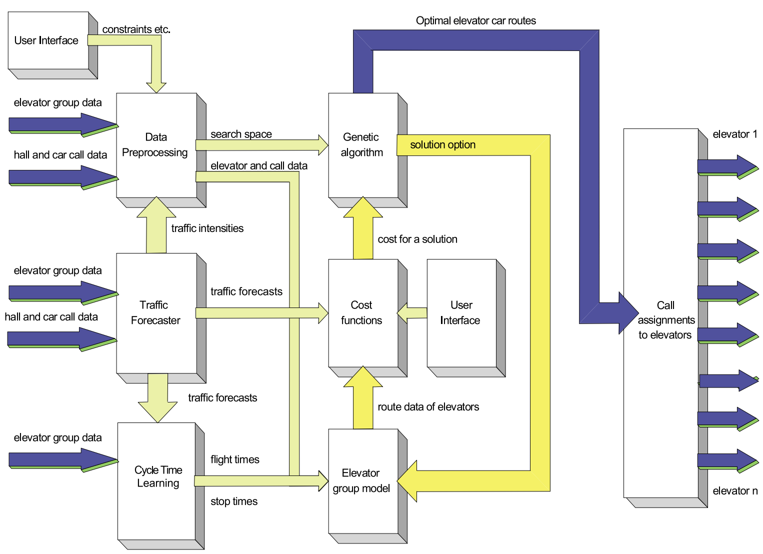

Fig.1 Block diagram of the call allocation algorithm

Accurate flight and stop times of each elevator for every 'pair' of floors in the building is learned by Drive Time Learning (DTL) and Stop Time Learning (STL) modules.

Traffic patterns recognition is based on the statistical forecasts. The control system starts to adjust for peak traffic periods in advance, before the peaks occur. When the optimum route for the elevators to serve landing calls has been found, the calls are assigned accordingly. The landing calls are allocated to the best elevators at least twice a second.

ARTIFICIAL INTELLIGENCE

The TMS9900 GA group control with artificial intelligence is described in Fig.2. The passenger traffic information is handled in four stages.

First, the passenger traffic flow is measured using load weighing device and photocell signals and saved in the short-term and daily statistics together with other traffic events, such as registering and canceling of landing calls. Statistics for the number of entering and exiting passengers per floor is gathered for the whole day in five-minute periods.

Once a day the previous day statistics are saved in the longterm statistics (statistical forecasts). At this second stage, exponential smoothing is applied when adding the new data. The forecasts are made for each day of the week.

At the third stage the statistical forecasts are utilized when recognizing the traffic pattern. The fuzzy limits of the traffic patterns are modeled using fuzzy logic. Finally, the measured passenger traffic and the prevailing traffic pattern information are used to allocate the landing calls and to dispatch the elevators.

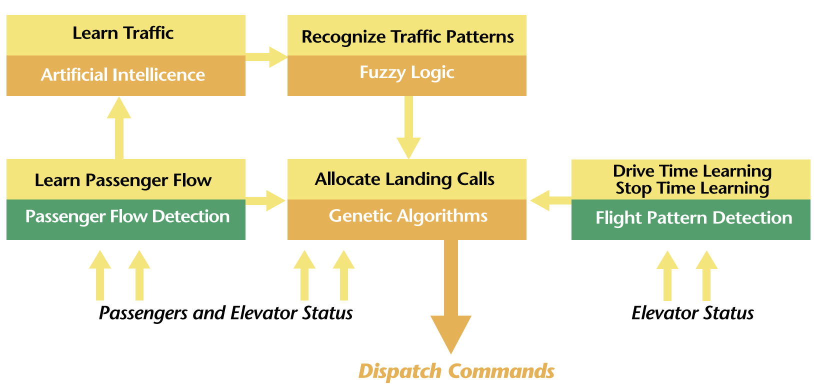

Fig.2 TMS9900 GA group control with artificial intelligence

The call allocation is based on Genetic Algorithms. During heavy traffic peaks extra cars can be dispatched to the busiest floors according to the forecasted traffic pattern, or e.g. the Concentrated Passenger Service (CPS) feature can be used to increase the handling capacity of the elevators during incoming peak. During light traffic, cars can be parked automatically, in equal traffic zones at the floors with most traffic.

STATISTICAL FORECASTS

Long-term statistical forecasts of the passenger traffic are stored, and utilized in several control operations. Actual measurements in buildings indicate that the traffic is quite repetitive from day to day. In most situations a Single Exponential Smoothing method gives the best statistical storage result (see the formula below).

$F_t = \alpha Y_t + (1-\alpha) F_{t-1}$

Where: F = the smoothed value, and
α = the smoothing constant, with a value between zero and one.

This method decreases exponentially the relative portion of the old data, which is gradually replaced by new data added. If the traffic in the building changes, it is learned. In other words, the statistical forecasts, stored in five minutes periods for every weekday will adapt to any changes in the building.

In the first month, the initialization phase following the commissioning of the system, only statistics are gathered. During that time the group control does not use the forecast data, which means the system operates at a reduced control efficiency, as the landing call times are optimized by the basic call allocation algorithm instead of passenger waiting and journey times.

Statistics for a whole day are collected before being used to modify the statistical forecasts. Seasonal variations in the measured traffic data are eliminated by the calendar and by two acceptance tests. These tests ensure that periodical changes, such as Christmas, are excluded from the statistical forecasts. Exceptional days, or failures to record the data, are eliminated from the statistics.

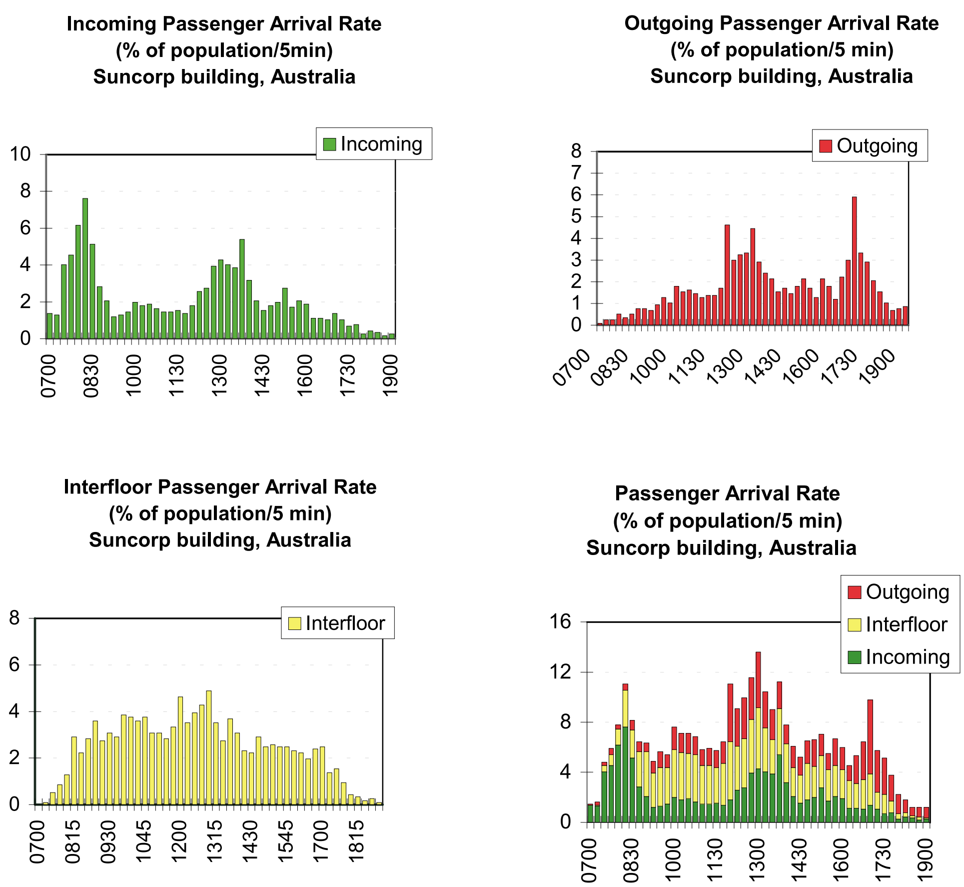

Fig.3 Statistical forecasts of the passenger traffic at the Suncorp Building, in Brisbane, Australia

FUZZY LOGIC

The traffic patterns are based on the forecast statistics and are defined using fuzzy logic. The passenger traffic flow is divided in three components, “incoming”, “outgoing” and “interfloor” traffic according to the floor where a passenger has boarded and exited the car. The total number of passengers that usually use the elevators in each five minute interval, refers to the “traffic intensity”. The traffic components and the traffic intensity are searched from the statistics for the next five minutes period. Traffic type is deduced comparing the traffic components with 36 fuzzy rules. The relative portion of the each traffic component gets a value LOW, MEDIUM or HIGH (see Fig.4). The traffic intensity is compared to the handling capacity of the elevator group, and it gets one of the values LIGHT, NORMAL, HEAVY or INTENSE (see Fig.5).

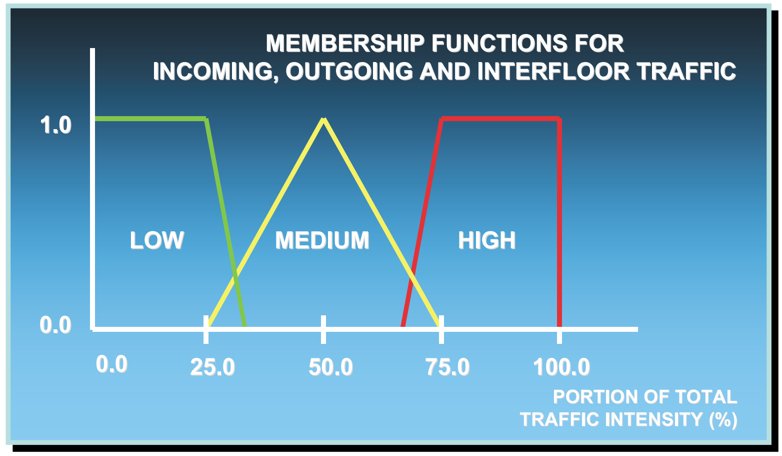

Figure 4. The degree of membership of the traffic components

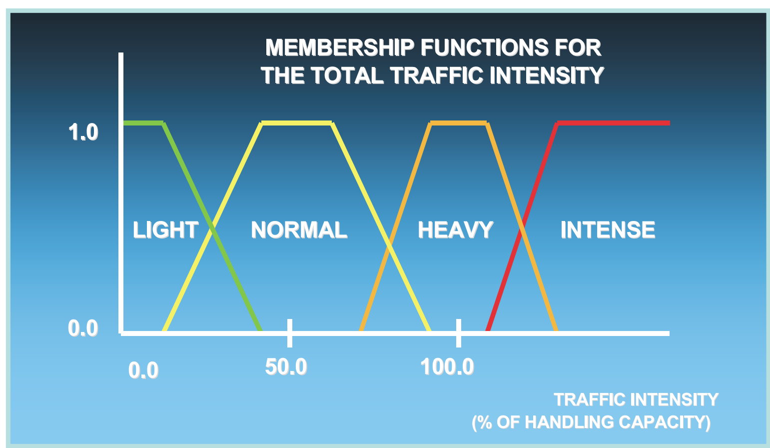

Figure 5. The degree of membership of the total traffic intensity

An example of a fuzzy rule for up-peak:

IF the traffic intensity = HEAVY *and*
incoming traffic = HIGH *and*
outgoing traffic = LOW *and*
interfloor traffic = LOW
THEN the traffic pattern = UP PEAK

All the rules are compared and the rule that best matches the forecast five-minute situation is selected.

ELEVATOR ROUTING WITH GENETIC ALGORITHM

The most effective way to allocate landing calls to elevators would be to search through all possible combinations of assigning cars to the calls and to select the combination that gives the best value for the optimization target, e.g. shortest passenger waiting times. The number of alternative ways to allocate landing calls to elevators, i.e. number of routes, is L^K, where L is the number of elevators and K is the number of landing calls.

There is however a combinatorial explosion in the number of possible routes as the number of floors and elevators increases. For instance, there are over 10^{36} alternative ways to serve the landing calls in a twenty-floor building with eight-car group of elevators if all landing calls were active. It is clear that computing all the route alternatives is beyond even a medium size elevator group despite the processing power of modern computers.

To reduce the number of route evaluations the optimal route search of the TMS9900 GA is based on Genetic Algorithm, which is able to find optimum solutions without systematically going through all the possible combinations.

The algorithm simulates nature: It models the evolution of a small population in the computer's memory. Whereas one generation in real life takes tens of years to develop, one generation inside computer is simulated in just a fraction of a second.

The population is formed by a set of solution alternatives, called chromosomes, constituted of genes. As in nature, genetic phenomena like "selection", "cross over" and "mutation" are applied to the chromosomes. The genes will have to 'fight' for their right of survival. Only the best chromosomes and genes, i.e. the best routes, of each generation survive and are able to reproduce a subsequent generation. At the end, typically after 50 generations, the population contains the best solution to the problem - the optimal routes for the elevators. A bank of genes reduces the computation time still so that the optimal solution for all kinds of lift banks is always found in real time. This powerful natural mechanism, which in fact has produced and continues to influence all the creatures in the world, has been successfully applied to solve the elevator call allocation problem.

With Genetic Algorithms there is the question how to map the real life problem to chromosomes, or more precisely to the genes of the chromosome. Fig.6 illustrates the principle.

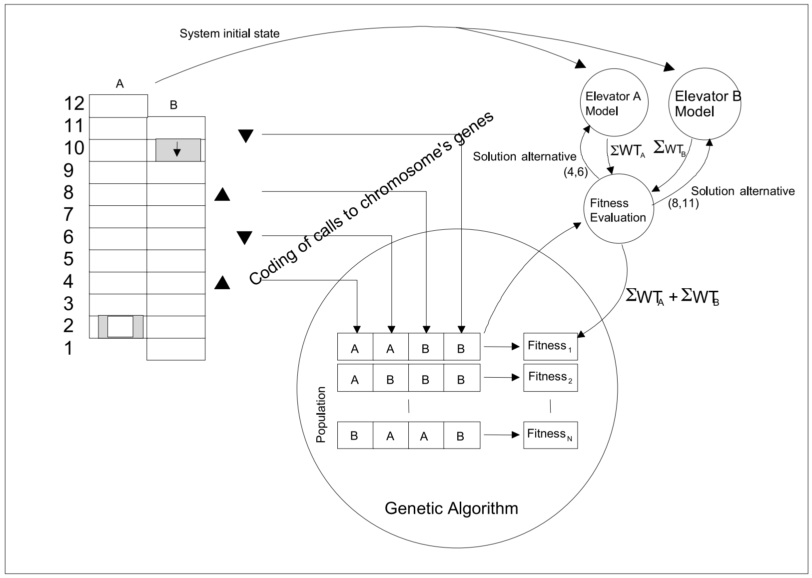

Fig.6 The elevator routing principle of the TMS 9900 Genetic Algorithm

Let us consider a group of two elevators (A and B) and four active calls at floors 4,8,11 and 6 (Fig.6). Each active call in the group is coded as a gene inside the chromosome. The position of the gene in the chromosome ("locus" in GA-terminology) contains the information of the floor where the call comes from while the value of the gene ("allele") describes the elevator that is going to serve the call.

The first chromosome in the population proposes a solution: elevator A to serve 4^{th} and 6^{th} floor calls, while elevator B serves the 8^{th} and 11^{th} floor calls. The "fitness" of the chromosome is evaluated, considering the elevator arrival times to the calls when calculating passenger waiting times WT according to the route the chromosome represents. Cross-over and mutations between the best chromosomes are tried and after several generations the chromosome with best alleles is found, this being the optimum solution.

IMPROVEMENT ACHIEVED

Fig.7 presents the relative performance of a number of generations of group control systems measured in an actual building: The original microprocessor system was modernised by KONE TMS900 which, in turn, was replaced by TMS9000 using call allocation based on Enhanced Spacing Principle (ESP); the system was later updated with an AI module. The TMS9900 GA values are obtained through simulation. The improvement in terms of passenger waiting and call times is significant.

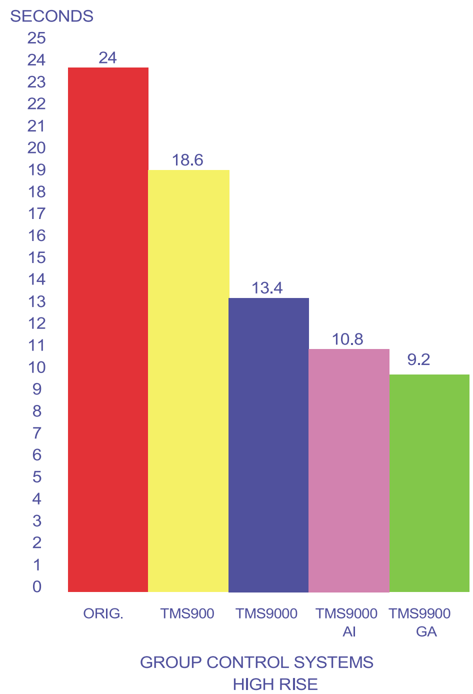

Fig.7 Call times measured at the National Mutual building in Sydney, Australia.

TMS9900 GA provides following advantages when compared to preceding high rise control TMS9000:

- on the average 15% shorter mean passenger waiting times
- maximum waiting times are shotened, too
- at peak traffic hours handling capacity increases ca. 10%
- cars travel with less passengers
- elevator group runs shorter total distance.

GROUP COMPUTER UNIT

The TMS9900 GA group computer unit is based on industrial PC-technology (Fig.8). The system options include a backup group control computer that is normally passive takes over in the unlikely case that of group control computer failure.

In addition, each elevator controller includes a group control operation with ESP principle. These features

render the group control literally fail-safe.

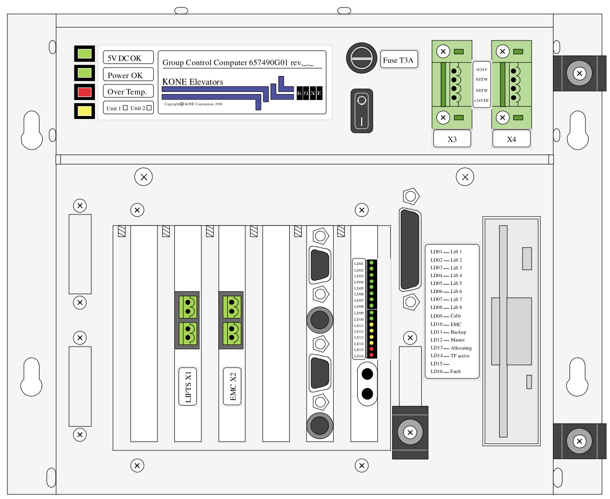

Fig.8 TMS9900 GA group computer unit

Modern industrial PC-technology with large memory capacity and high clock frequencies offers plenty of processing resources, accommodating control features that were difficult or impossible to implement in the past.

SERTRANS™ ARCHITECTURE

The elevators in a group communicate with a local area network within a distributed KONE SerTrans™« control system (Fig.9).

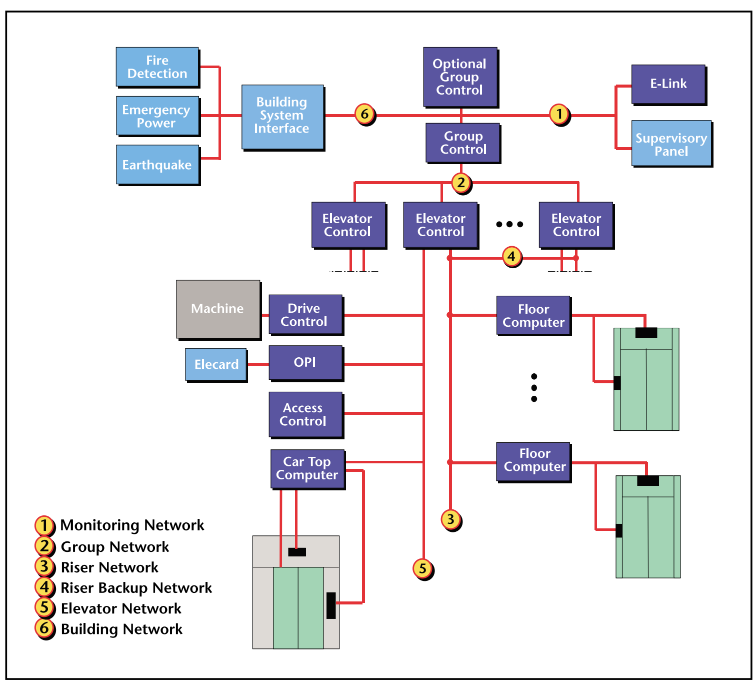

Fig.9 KONE SerTrans™ local area network

The local area network technology is common for example in the automotive industry, where it has been tested and used for a number years. The TMS9900 GA control system is extremely reliable: A component failure has zero or minimum influence on the other components within the network.

Within the "SerTrans™" network all the devices are 'intelligent' and are connected to the local area network by one twisted pair of cables. The distributed control system drastically reduces the number of cables and connections compared to a system where all elevator control is centralised to the machine room. The reduced number of cables decreases the sensitivity of failures and promotes both system reliability and installation quality.

OPERATOR INTERFACE

The TMS9900 GA controllers are adjusted to the environment during commissioning of the elevators. The building specific control features are memorised on a 'flash card' inserted in the Operator Interface (OPI) panel (Fig.10). The card serves as an access tool, enabling resetting control parameters, as necessary. It is possible to use several cards with different configurations: for example, one is used to set up elevators for the temporary building´s construction time use while another card contains the configuration for the final use. Plug-in connections facilitate the use of either temporary or permanent operating fixtures.

Fig.10 TMS9900 GA Operator Interface panel

The OPI is located on the elevator controller and consists of a display screen, keyboard and indicators. It provides information and allows adjustments of the control parameters.

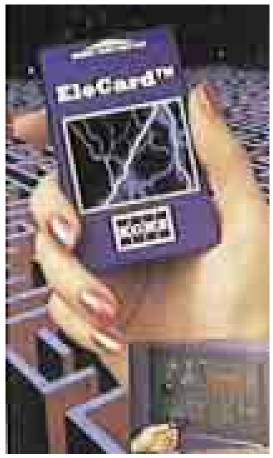

Fig.11 KONE EleCard™ configuration card

Examples of the commands enabled by the OPI:

- Identify and register landing and car calls
- Identify elevator position and direction of travel
- Verify that a car is correctly at a floor level
- Open and close the car doors
- Check the system condition (fault, safety and status indicators)
- Check the fault log
- Modify operating parameters of the elevators such as the door times, signalization etc.
- Adjust parameters or add optional features, such as car parking

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