Continental Automated Buildings Association

Elevator Systems for Future Intelligent Buildings

Part 2: Remote Control and Monitoring, and Emergency Operation

A CABA WHITE PAPER

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CABA Intelligent Buildings Council

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TABLE OF CONTENTS

1. ABSTRACT

In Part 1 of this series, we looked at the two important issues of elevators that serve super high-rise and wide buildings. To accelerate a large moment-of-inertia required for a high-rise elevator, driving motors with huge torque-to-size ratios must be used, such as "permanent-magnet synchronous motors." Another requirement of super high-speed elevator is in-car pressure control. Multiple elevator cars moving along the same hoistway make efficient use of the long hoistway. They are designed as "ropeless elevators" with "linear permanent magnet synchronous motors." To serve super wide buildings, "ropeless" elevators must be able to move both vertically and horizontally. In this part, we examine safety issues of such elevators including remote control, monitoring and maintenance, and emergency operation.

2. REMOTE CONTROL, MONITORING AND MAINTENANCE

Remote alarms and monitoring of elevators have been key features desired by owners of intelligent buildings. According to Chapter 14 of *Transportation Systems in Buildings - CIBSE Guide D 2015*, there are many features and advantages for adopting remote monitoring, including, but not limited, to:

i) fault monitoring so that a service contractor can be notified immediately whenever a problem, or more precisely, a fault occurs;
ii) condition monitoring to monitor real-time parameters such as the number of starts/stops, hours of service, and other operational statistics to facilitate a more efficient and selective planned maintenance;
iii) status indication to let everybody know that captioned elevators are operating normally with the aid of graphical displays;
iv) performance monitoring so that a more realistic traffic analysis could be conducted;
v) remote control that is usually confined to actions that a normal passenger is allowed to carry out, such as landing/car calls, and operation of door control buttons, etc.; it would be very dangerous if an elevator could be stopped remotely or vital parameters such as rated speed, door timings, etc. could be adjusted remotely;
vi) alarms to monitor site personal safety, watchdog, and any unauthorized entry to the machine room or the elevator shaft;
vii) video to monitor the in-car status with the help of a CCTV camera; and
viii) nuisance operation of emergency alarm buttons to avoid unnecessary on-site attendance by the maintenance contractor, fire department or police.

Remote monitoring of elevator systems is not new. Decades ago, some manufacturers established national centralized monitoring centers to remotely monitor the status of elevators under their maintenance in order to enhance the efficiency of attending fault calls by technicians and to reduce the breakdown rate by providing statistics based on ample supply of data. However, such provision has normally not been available to the owners or users of the elevators. In other words, elevator owners have no way of retrieving such statistical data from the center. Furthermore, when the elevator is no longer maintained by the manufacturer, such service disappears immediately because the protocols used to transmit data have all been proprietary, not freely open to the users. A universal monitoring system that is owner- and user-based is desirable.

Earlier this century the Singapore government started to monitor all elevators operating in public housing communities through Surbana Jurlong, a government-owned private limited company. Now, the system is monitoring over 24,000 elevators around the country with tailor-designed software for predictive maintenance of elevators. Monitoring is not only for safety devices and power supplies; there is continuous CCTV recording transmitted to a central database. When any incident occurs, it is always possible to obtain a video clip of the occurrence from the cloud. This may be an important feature of a smart city.

In mid 2015, Microsoft jointly with ThyssenKrupp applied HoloLens technology to enhance maintenance service. Thousands of sensors and systems in elevators were connected to the cloud. Then, Microsoft Azure IoT Suite was employed to capture useful elevator data, from motor temperature to shaft alignment, car speed, and door functioning, and transmit the data to the cloud for display on a single dashboard. This system provided technicians with instant diagnostic capabilities and rich, real-time data visualization of two primary types of data: alarms that indicate an immediate issue; and events that are stored and used for management.

2.1 Connection between an elevator and the building management systems

Connecting an elevator system to the building management system (BMS) is not new; it has been done for more than 30 years. However, it has been on a project-by-project basis, and the cost to implement such service has not been low. As mentioned earlier, the main problem is the lack of a set of common and open protocols, objects to be more precise, that are tailor-designed for elevator operation. In the HVAC and lighting industry, open and common protocols have been available for at least two decades.

Internet connectivity using TCP/IP is not a complete open solution, because different brands can still implement proprietary communication objects, making global interoperability impossible and creating challenges for each installation. At present, the most reputable open and common protocols for high-level building management or automation are LonWorks, BACnet, and Konnex, while others like CANBus and ModBus are used at the device level.

For example, there are some standard functional profiles available on Lon, such as access controller, indicator, position indicator, message display, hall lantern, arrival gong, car-direction lantern, and voice announcer, etc. They are all built upon existing standard network variable types, SNVTs, not custom created for each elevator installation. Examples of Lon SNVTs are "SNVT_str_asc" for floor name, and "SNVT_switch" for direction of travel, etc.

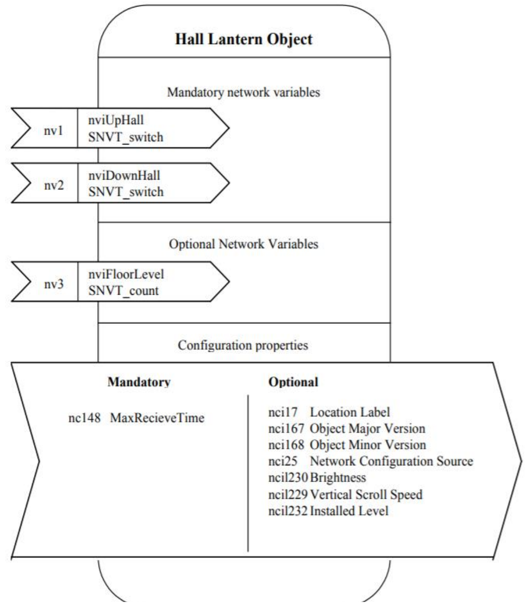

Figure 1: LonMark functional profile of a hall lantern: "UpHall" indicates an up-traveling car; "DownHall" indicates a down-traveling car; "nvi"means an input network variable of the type "SNVT switch".

Figure 1 shows the "Hall Lantern Object" of a LonMark functional profile. In this object, there are two mandatory network variables indicating the direction of movement of the elevator car, conveyed by the standard network variable type, Switch. Such a variable type is commonly found in many controllers, such as a lamp switch. It indicates whether the variable is on or off with a value from 0 to 200, a precision of 0.5%. The optional network variable shows the position in terms of floor level of the elevator car, conveyed by the standard network variable type, Count, which is an "unsigned long" of two bytes in size with a minimum value of 0 and a maximum value of 65536. Furthermore, the network variable type Str-Asc is a character string up to 30 characters. Other standard network variable types such as "SNVT_motor_state", "SNVT_power", "SNVT_amp" and "SNVT_elec_kwh" are also used in an elevator system.

Such limited amount of profiles or objects is far from enough for the BMS to monitor the whole elevator system. That explains why for any project that needs a connection, the BMS has to be programmed to understand the proprietary protocols used by the elevator system to achieve comprehensive integration.

2.2 My consultancy project and the development of BACnet objects for elevators

I was engaged by the Hong Kong Special Administrative Region government in 2006 to develop a set of common and open protocols to monitor thousands of elevators owned by the government. The developed protocols should be both machine and platform independent, making time-consuming collaboration between each elevator company and the BMS supplier unnecessary for each integration project. It took almost one year to finish the report, which suggested three approaches: the use of LonTalk, BACnet, and XML. The three systems, involving the development of a universal lift and escalator gateway (ULEG) for converting the proprietary protocol of the elevator supervisory controller to our open protocol, were installed and tested at two buildings belonging to the government in Hong Kong. The block diagram is shown in Figure 2. We understood that the manufacturers were not willing to open their proprietary protocols to the general public. So, we developed a gateway that talks to the elevator controller via the proprietary protocols while the connection of this gateway to the Internet is based on common and open protocols. Inside the ULEG was a port for connecting to the elevator supervisory controller, and the scanner, which was responsible for digesting messages from the controller and initiating messages to the controller. The converter inside the scanner then translated the manufacturer proprietary proptocol into a standard set of protocols, called dirty protocols by the consultancy team, DP. Three reporters, the XML reporter, the BACnet reporter and the LonWorks reporter, were built inside the ULEG, which was actually a desktop computer..

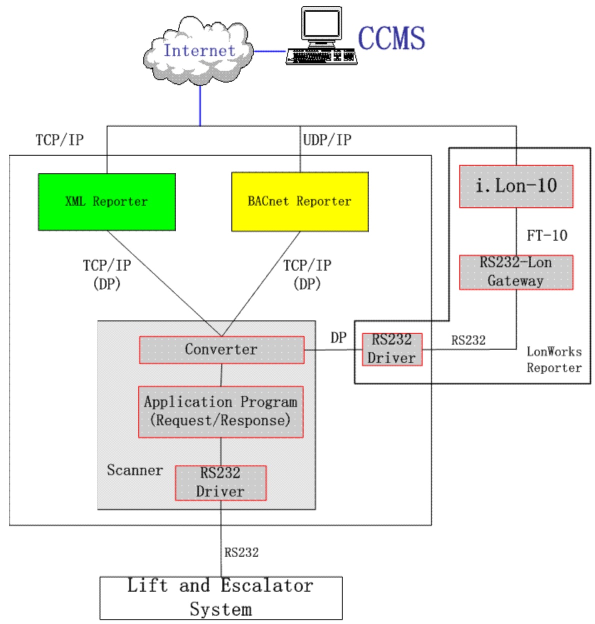

Figure 2: Architecture of ULEG (Universal Lift and Escalator Gateway).

After the project was completed, I met Bill Swan, nicknamed “BACnet Bill”, who had been the chairman of ASHRAE’s SPC 135 for several years. He was very interested in elevator systems and supportive, and we worked together to produce the first draft of elevator related BACnet objects in early 2010. Unfortunately, he suddenly passed away in mid 2011, and it took five years for the relevant BACnet Working Group on Elevators and Vertical Transport to go through four public reviews. Finally, in February 2016, the objects, COV property multiple services and a new fault algorithm FAULT_LISTED, were approved as an official Addendum “aq” to ANSI/ASHRAE Standard 135-2012 and are now a part of the standard.

In the addendum, the elevator group object type defines a standardized object whose properties represent the externally visible characteristics of a group of lifts or escalators (a group being defined as those lifts or escalators controlled by a single supervisory controller). In the elevator group object type, there are properties like machine_room_ID, group_mode, landing_calls, and landing_call_control etc. Under the group, we have lift object types and escalator object types. In the lift object type, there are properties like car_position, car_moving_direction, car_door_status, energy_meter, out_of_service, and fault_signals, etc.

Property Identifier	Property Datatype	Conformance Code
Object_Identifier	BACnetObjectIdentifier	R
Object_Name	CharacterString	R
Object_Type	BACnetObjectType	R
Description	CharacterString	O
Status_Flags	BACnetStatusFlags	R
Elevator_Group	BACnetObjectIdentifier	R
Group_ID	Unsigned8	R
Installation_ID	Unsigned8	R
Floor_Text	BACnetARRAY[N] of CharacterString	O
Car_Door_Text	BACnetARRAY[N] of CharacterString	O
Assigned_Landing_Calls	BACnetARRAY[N] of BACnetAssignedLandingCalls	O
Making_Car_Call	BACnetARRAY[N] of Unsigned8	O
Registered_Car_Call	BACnetARRAY[N] of BACnetLiftCarCallList	O
Car_Position	Unsigned8	R
Car_Moving_Direction	BACnetLiftCarDirection	R
Car_Assigned_Direction	BACnetLiftCarDirection	O
Car_Door_Status	BACnetARRAY[N] of BACnetDoorStatus	R
Car_Door_Command	BACnetARRAY[N] of BACnetLiftCarDoorCommand	O

Figure 3: Some properties under "Lift Object Type" as extracted from Addendum "aq" to ANSI/ASHRAE Standard 135-2012.

Some properties under the "Lift Object Type" are shown in Figure 3, "R" for required and "O" for optional. Readers who want to know more about the history of development may read the two articles (So 2014b, So 2014c.)

One last point to mention is "remote control". Though remote monitoring can be freely implemented, remote control has to be implemented very carefully. It is dangerous to stop or change direction of motion of a running elevator car suddenly via remote control. Therefore, in our consultancy project and in the BACnet objects recently approved, only control commands that can be executed by a passenger on-site are allowed. These are limited to two: pressing a car call or a landing call.

2.3 The future of remote monitoring and control

The ability to connect, collect and analyze data from an elevator or escalator of course benefits all stakeholders. However, in practice, this is not that straight forward. According to Zauner (2017), finding compatible hardware and software is difficult, and collecting a mass of data without knowledge of how to analyze it is not helpful. More important, the system must be secure, and the information on it must not easily be accessed by unauthorized outsiders.

The proliferation of data collection and analysis under the banner of Internet of Things (IoT) may be a current trend, but it poses challenges for elevator data. According to Bryant et al, (Bryant et al. 2017), to implement IoT on elevator systems, the manufacturers would need the following stages of product development:

i) diagnostics of raw data – interpreting raw signals;
ii) alerting – using signals to alert the user when the elevator is out of order;
iii) top down engineering – from systems to subsystems with increasing detail; and
iv) sensors, communication, cloud, and machine learning – provide actionable information via automatic diagnostics and self-learning adaptive algorithms.

In this case, some new strategies of maintenance (Bryant et al. 2017) could be achieved, such as:

i) proactive maintenance – maintenance is performed only when certain indicators show signs of decreasing performance or imminent failure, where sensors create an alarm at each deviation, versus the existing regular and preventive maintenance adopted by the industry;
ii) predictive maintenance – determine the condition of in-service equipment to predict when maintenance should be performed in order to maximize uptime; upon generating data during operations, a breakdown probability is defined, and counter measurements within certain intervals are established; and
iii) prescriptive maintenance – instead of predicting failure, it produces outcome-focused recommendations or scenarios for operations and maintenance from prescription analytics; it not only informs the user when a failure is to occur, but also provides the user with a choice of scenarios from which the best action can be picked.

Prescriptive maintenance very much relies on cloud-based collection of data, machine-to-machine communication, intelligent raw data analysis, and machine learning. This is the future of remote monitoring.

Remote control, subject to safety consideration, will be limited to certain criteria. As mentioned in the previous section, remote control is restricted to some actions that can be done by on-site passengers, such as making a landing call or a car call. Hitachi (Takao et al. 2017) developed a system that integrates data from sensors and images from cameras to enhance passenger service. When a trapped-passenger incident occurs, the system remotely analyzes the failure state and helps to rescue the trapped passengers as soon as possible, while maintaining voice communication. Trapped passengers are able to talk to and see staff in the emergency call center, and vice versa.

As explained, the ULEG included a translation function from manufacturer proprietary protocols to a common open protocol. This translation function is related to the concept of APIs (application programming interfaces). These are commonly employed in the telecommunication industry for smart phones and tablets. Product designers of these smart devices must provide software access for applications designers to control and retrieve information from the products. But at the same time, access for observing and controlling the internal functions of the smart devices must be carefully managed and limited in order to preserve stable operation of the devices. Dr. Kenneth Wacks (Wacks 2014) chairs an international committee on Home Electronic System (HES) that has developed standards for product interoperability. The ISO/IEC 10812 series of standards, “Guidelines for Product Interoperability,” introduced specifications for one open protocol called the Inter-Working Function (IWF) to facilitate commands and data exchange among incompatible proprietary devices. The IWF allows proprietary systems to work as if they have common APIs. The concept of ULEG could be implemented with an IWF according to these ISO/IEC standards. Elevator manufacturers should adopt this ULEG+IWF approach so that proprietary protocols can still be run inside the supervisory controllers, which can communicate with different models of BMSs via an IWF. The IWF might be based on BACnet or a generic protocol if more acceptable to the manufacturers.

With advances in IoT technology, interoperability methods, and the popularity of the "smart city" concept, remote monitoring of elevators will be commonly found everywhere to enhance passenger safety, convenience and comfort, and to predict the occurrence of faults, fix problems as soon as possible, and ensure that downtime is kept to a minimum by predicting failures and automatically selecting the best action for an incident.

3. EMERGENCY OPERATION

The sign, "In case of fire, do not use elevators, use stairs," or similar wording, is commonly found at elevator lobbies across North America and elsewhere. Most people have been educated to the concept that they should leave a building via a stairway in case of emergency. Code makers have traditionally preferred this concept, although the use of "firefighting elevators" or "firemen's lifts" by emergency personnel during a fire outbreak has been an established practice for decades.

However, the 9/11 terrorist attacks forced elevator professionals and code makers to start thinking about whether such a concept should still be enforced today – in particular, where super-high-rise buildings are concerned. The United States could be regarded as the pioneer in the world in this area of development.

A workshop on the "Use of Elevators in Fires and other Emergencies" was held in 2004 and organized by the American Society of Mechanical Engineers (ASME), National Institute of Standards and Technology, International Code Council, National Fire Protection Association, U.S. Access Board, and International Association of Fire Fighters. After the workshop, two ASME A17 Task Groups were formed to study the use of elevators for occupant egress and firefighters respectively. In 2013, the new edition of ASME A17.1/CSA B44 was published, in which the concept of "Occupant Evacuation Operation" (OEO) was defined as "the operation of an elevator system for occupant evacuation under emergency conditions." It provides for elevator service from a zone of fire-affected floors (i.e., the fire floor, two floors below, and two floors above) to the emergency exit floor, usually the ground floor, and the car with such a service is called "Occupant Evacuation Elevator" (OEE). This involves automatic operation of the elevators without any attendant inside the car. One point is critical: if one elevator is designed as an OEE, all other elevators serving the building must also be OEEs.

In Europe, *BS 9999: Code of Practice for Fire Safety in the Design, Management and Use of Buildings*, published in October, 2008 stipulated the use of an attendant-controlled elevator for helping disabled occupants leave the building in case of emergency. An attendant must be present to control the elevator, while a fire coordinator stays at the main emergency-exit floor to co-ordinate the evacuation. *CEN/TS 81-76: Evacuation of Disabled Persons Using Lifts* published in 2011 also called upon an attendant. ISO/TS 18870:2014 got a similar concept with the OEO of ASME A18.1-2013.

The use of elevators for emergency egress is gradually being accepted by code makers worldwide . However, in an emergency, even if elevators that are smoke, fire, water, steam, explosion proof, etc. are available, building occupants may not have the patience and confidence to wait for elevator services at the fire floor or floors nearby. Previous research by Emma Heyes (Heyes 2009; Wit 2010) showed that the percentage of total potential passengers that are willing to wait during emergency, W%, decreases with acceptable waiting time, T in s, but increases with travel height, the Nth floor, by the formula, $W = N \times (1.06 - 0.0016 \times T)$, $5 \le N \le 60$, and $0 \le T \le 600$. That means if passengers are located at the 60th floor, only 46% of all potential passengers are willing to wait an elevator for three minutes. Moreover, my opinion is that in an emergency, human beings can easily turn unruly. Politeness and consideration disappear. Therefore, the design must account for the psychology of passengers, human behavior, as well, in addition to the technologies necessary to ensure reliability, robustness, and safety of the entire operation. A design was proposed (So 2014f) that ensures occupants feel comfortable enough to wait for elevators in order to leave the building in an emergency safely, quietly, and considerately.

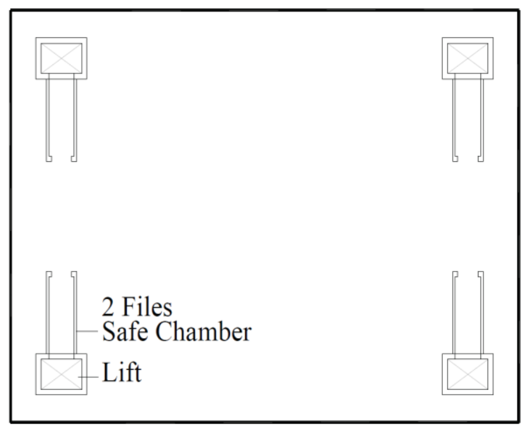

Figure 4: Refuge floor plan designed with designated elevators at building corners.

Usually for high-rise buildings there is one refuge/rescue floor for every 20-25 floors. During emergency, healthy evacuees can easily walk down 20 floors or up five floors via the pressurized stairways to reach their nearest refuge floor which is well protected and safe, versus the regular elevator lobbies. Evacuation elevators, treated as normal elevators under non-emergency, are placed at the four corners. At the entrance to each evacuation elevator, a safe chamber made of concrete with a fire-resisting period of at least two hours is erected, shown in Figure 4. The chamber has a single-file entrance from the lobby, but a double-file width along the channel. In this case, evacuees can only enter the chamber one by one, then queue up two by two. A good order for entering the arrival car can be guaranteed. Nobody tries to overload a car, nor prevent the doors from closing because the two evacuees, who could do that, are closest to the doors and they clearly know they have top priority during the next trip.

Emergency situations include not only terrorist attacks but others, like major fire out breaks, hurricanes, major water floods, and earth quakes, etc. In these situations, a quick and safe building evacuation may be needed. In the past, elevators were not involved in such a procedure. Now, when we are talking about super high-rise buildings from hundreds of feet tall to possibly a mile high, elevators have to play a role. In the future, when all issues have been addressed, including human behavior, occupant evacuation elevators will become a norm in all high-rise buildings.

4. CONCLUSION

In this white paper, two issues related to smart elevators with state-of-the-art technologies and technologies for future intelligent buildings have been introduced: remote monitoring, control, and maintenance; and emergency operation. The first issue is closely related to information technology since we are dealing with open protocols and communications on the Internet, which are trends in the elevator industry. The second issue is becoming more critical because buildings are facing different types of disasters including terrorist attack. Emergency egress with high safety standards is necessary. Advanced technologies applicable to modern and smart elevators in these two aspects are being introduced for super high-rise buildings.

In the final paper of this series, we will discuss intelligent dispatchers and energy efficient operation. The former ensures that passengers are handled efficiently particularly during rush hours. The latter is an imperative for sustainable development and environmental protection.

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