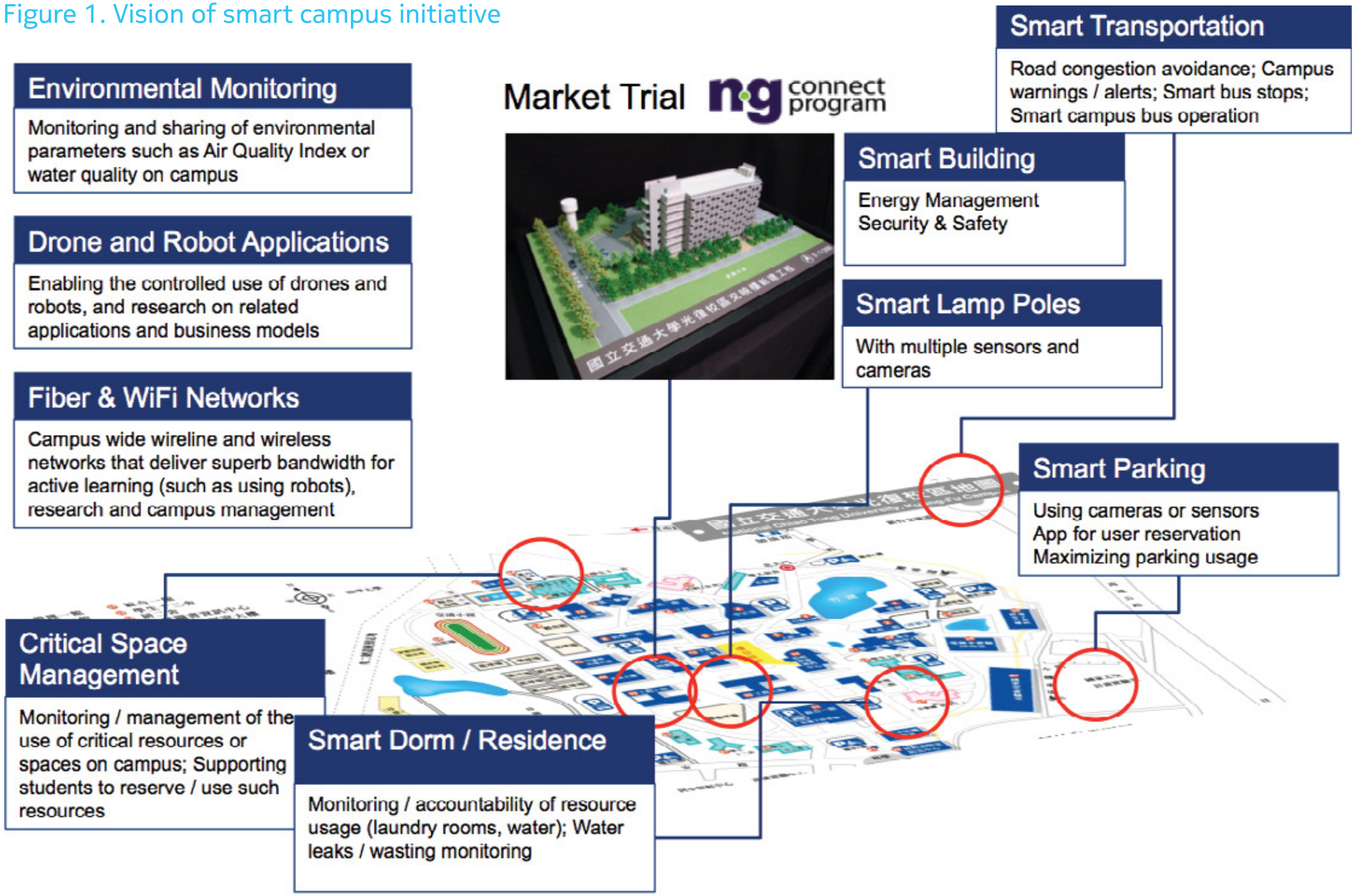
NCTU Smart Campus

Building intelligence into campus energy management

Collaborating with Nokia through the ng Connect Program, National Chiao Tung University (NCTU) deployed an Internet of Things (IoT) smart energy management platform that resulted in a reduction of building energy costs by more than 11 percent.

Figure 1. Vision of smart campus initiative



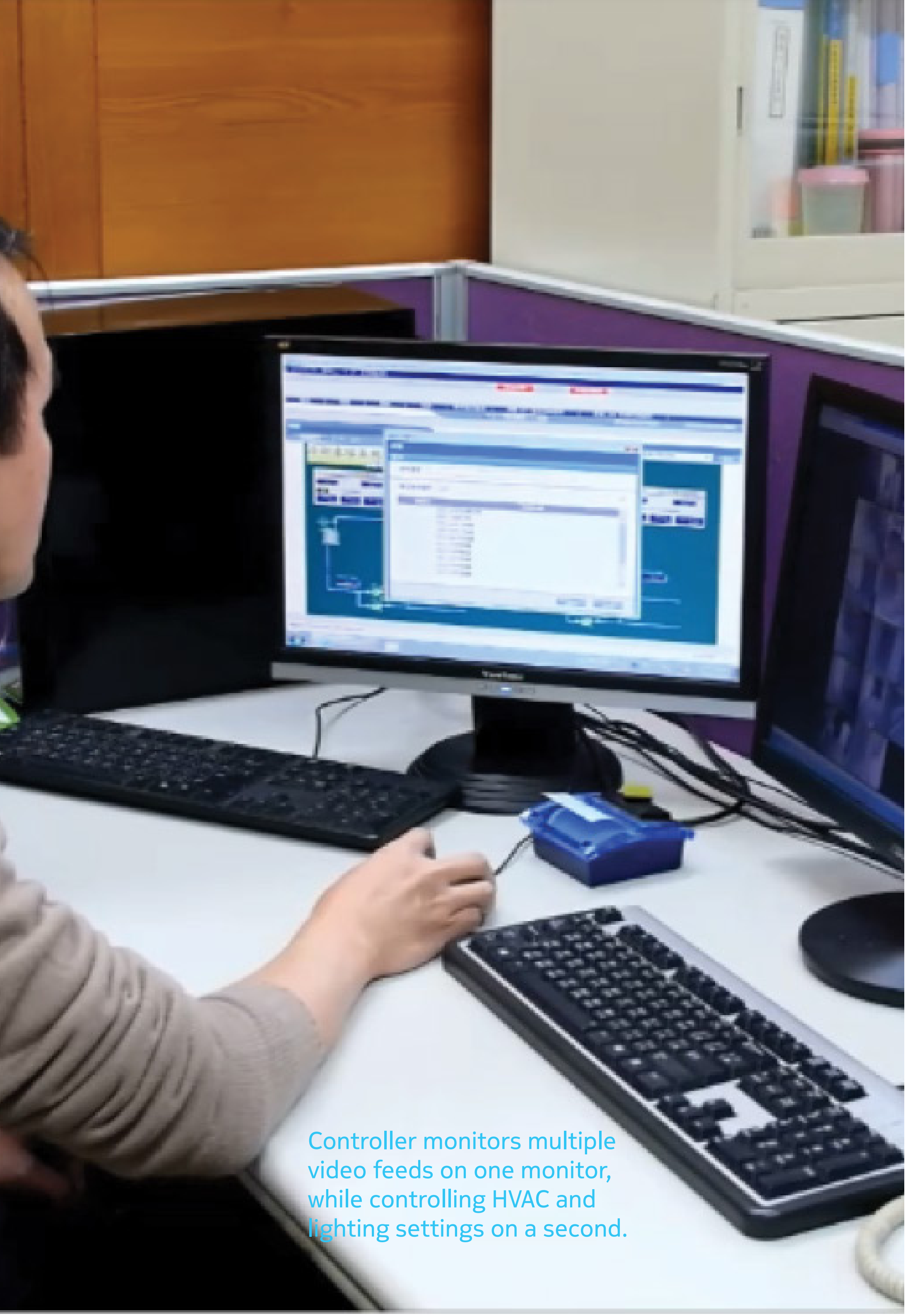
NCTU (National Chiao Tung University) is a leading University in Taiwan. In collaboration with Nokia, founder of the ng Connect Program, the university has been aiming to create a smart campus that can be used as a testbed for smart city technologies, applications, and the IoT (Internet of Things). As part of this broader challenge, NCTU, through a phased trial, wanted to develop a “smart building” management solution that could leverage IoT capabilities to significantly reduce the energy costs of its campus buildings.

The challenge

NCTU, much like most organizations that manage buildings, has struggled with the issue of providing comfortable building environments for occupants while balancing energy usage and costs. In fact, government energy reduction mandates to reduce energy use by one percent per year have driven the requirement to implement innovative ways to meet this goal. That’s important because studies of U.S. college and university buildings have found that about 67 percent of building energy costs are due to lighting, heating, and cooling, as well as installed equipment.[1] These factors are also driven by occupancy levels that can vary greatly depending on class schedules and special events.

A recent study indicated that, by carefully monitoring occupancy and performing analytics on occupancy data, energy savings of between 10 and 15 percent are likely.[2]

1 “Managing Costs in Colleges and Universities,” National Grid, 2003.
2 “Occupancy-Driven Energy Management for Smart Building Automation,”Agarwal et.al., BuildSys 2010 November 2, 2010, Zurich, Switzerland.



Controller monitors multiple video feeds on one monitor, while controlling HVAC and lighting settings on a second.

Phase 1 of the trial

As an element of its smart campus initiative, to better manage energy costs and provide occupants with a comfortable environment, NCTU, partnered with Nokia, founder of the ng Connect Program. Members of the ng Connect Program share the common goal of working with customers to successfully deploy new high-value concepts and services, including those using the IoT. Phase 1 of the trial hypothesis was as simple as it was clear: by leveraging existing video from security cameras, an operator could monitor and adjust HVAC settings based on concentrations of people.

For Phase 1 of the smart energy management trial, NCTU leveraged about 25 existing video security cameras that monitored areas where people tended to congregate. Viewing the video screens, a controller manually made decisions about turning lights and air conditioning on or off.

Because Taiwan Power charged the university peak rate from 07:00 to 22:00 pm, and most of the buildings were in peak operation during normal working hours (09:00 to 17:00 pm), the manual control function was applied between 09:00 am and 16:30 pm. After 16:30 pm, the control staff was off-duty.

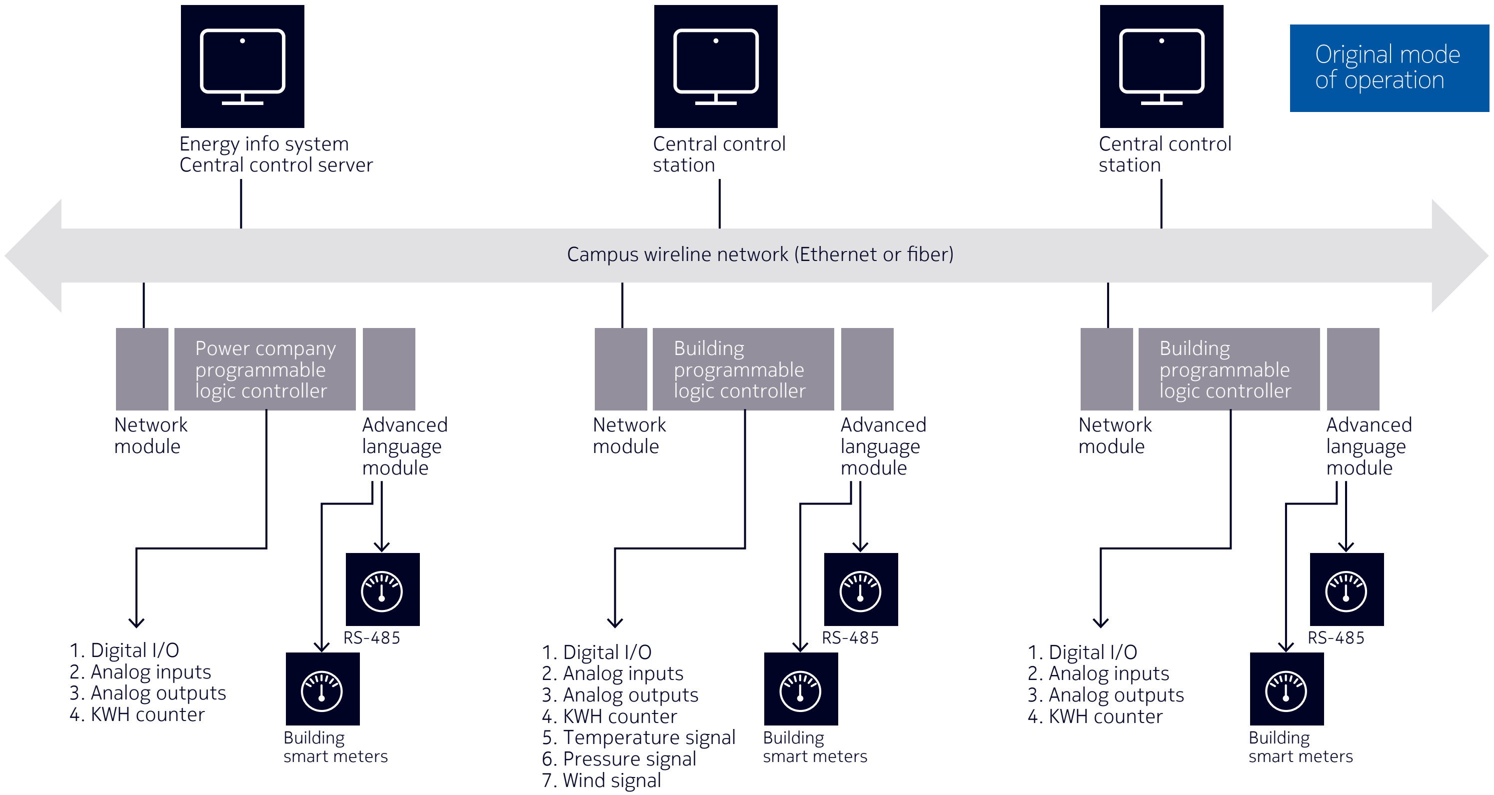
The controller's goal during operational hours was to minimize peak usage and bring daily usage within the daily target. The monitoring occurred Monday to Friday each week. During phase 1, there was no automated application that mapped the energy control units to the video feeds. The controller alone took action based on knowledge of which control units covered the areas observed through the cameras.

Controller decisions were based on whether people occupied or were using a space. No specific rules or guidelines for these decisions were implemented. As a result, decision latency depended on staff discretion and on the monitor's knowledge of how long a particular space was used. Decision latency also depended on whether people were likely to stay or go. Based on observation, the controller's decision typically came within one minute. Lag time was primarily due to the multiple feeds that the controller had to monitor. The resulting use of building energy was made available in hourly increments on an internal website; monthly statistics could also be generated.

The network used for the video feeds was an in-building LAN network. The network had a mixture of Ethernet and fiber networks that linked up different sections or rooms. As illustrated in Figure 1, the network was connected to the campus network. For the control portion, the programmable controller units (PCUs) were connected together with control stations using an IP network (Ethernet + fiber). Control commands were sent from control stations to these PCUs. The PCUs translated the commands into signals to the air conditioning units or other building equipment, such as water cooling units.

Figure 2. Pre-market trial configuration

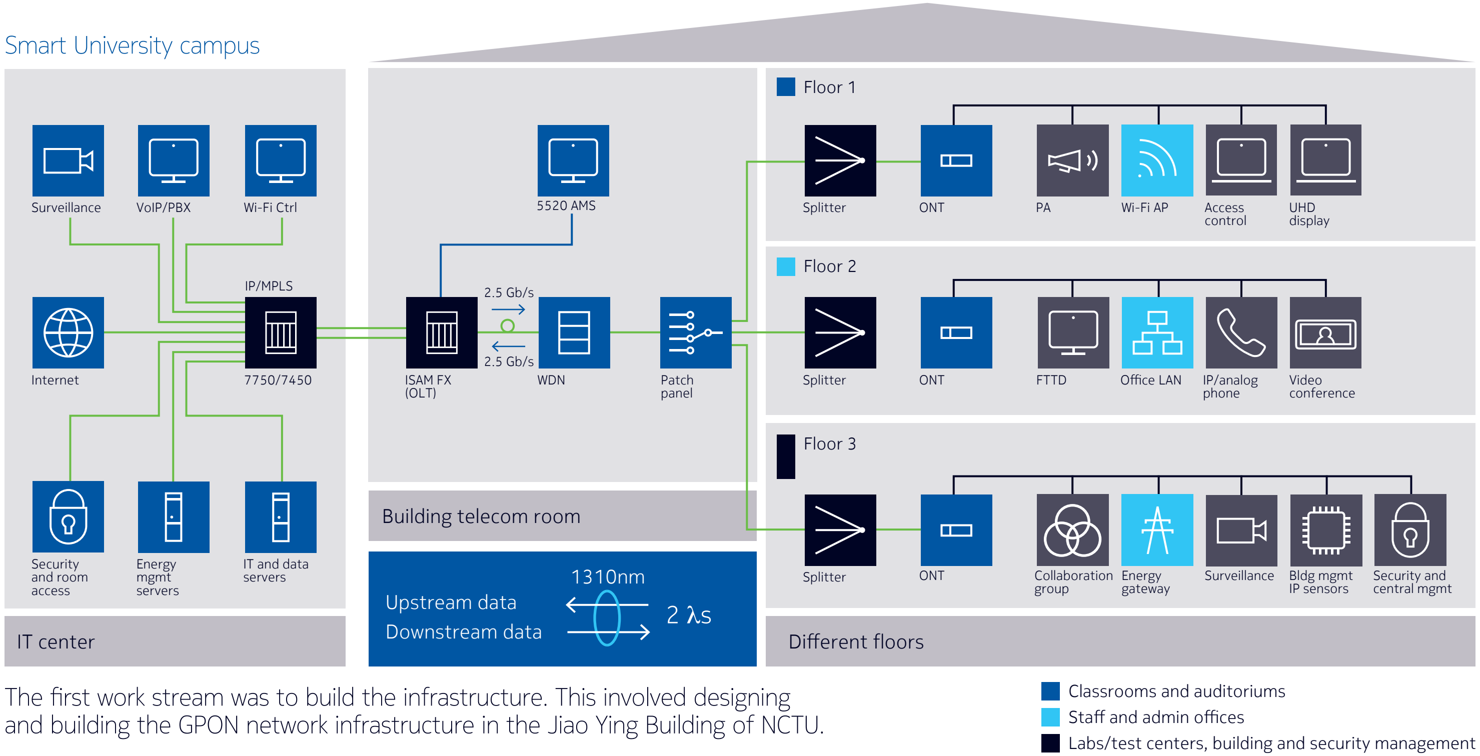
Energy information management system architecture
(Translated based on Ministry of Energy's Campus Energy Management Architecture)



These PCUs served as the gateways between the applications and specific equipment.

Phase 1.5, which is yet to come, will see the implemention of a real-time IMPACT dashboard. This will set the stage for Phase 2. By enabling additional sensors, Phase 2 will gather better human comfort level data, including localized temperature, humidity, and air flow. This data, coupled with automated analytics, will also include additional usage time and operate 24/7/365. The enhanced capabilities of better, continuous monitoring, as well as automated analytics, are expected to yield additional savings while freeing the human operator to perform other functions. As the pre-market trial continues, key questions remain: How much more energy and cost savings are attainable with the implemention of an IoT platform whose analytics and the addition of sensors can enable better decision making? Figure 2 illustrates the pre-market trial configuration.

Figure 3. NCTU Smart University Nokia-based network infrastructure



The first work stream was to build the infrastructure. This involved designing and building the GPON network infrastructure in the Jiao Ying Building of NCTU.

Why Nokia

As founder of the ng Connect Program, Nokia had established itself as a leading, innovative, and reputable voice in the ng Connect ecosystem — an ecosystem of market-leading companies that develops innovative solution concepts, business models, and market trials. By working with Nokia, NCTU knew that it would have access to a major innovator that had proven its leadership in infrastructure, devices, as well as applications. What's more, the ng Connect Program's ecosystem of innovators included companies sharing their expertise and technology to develop prototypes and market trials for IoT products, solutions, and services — an important dimension of NCTU's smart building energy management trial.

Solution

NCTU's solution of its energy management challenge began with the choice of the right infrastructure on which to build and manage an IoT platform and energy management system. Nokia built a NCTU campus-wide, leading-edge GPON network as the basis for the creation and testing of new smart campus services and applications. Using this infrastructure, the Nokia IoT platform (IMPACT) will be implemented to manage devices and connections, as well as enable data collection and analysis. As illustrated in Figure 3, these elements will combine to enable professors and students to invent, test, and trial new applications and services in a live environment.

While Figure 3 shows the overall, high-level network infrastructure architecture, the building energy management trial has its own architecture for Phases 1 and 2. These are shown in Figures 4 and 5.

The overall solution for smart building energy management is being implemented in three phases:

- Phase 1 – Leveraging the state-of-the-art network infrastructure and existing security cameras to enable manual analysis of video feeds and environmental adjustments. (See Figure 4).
- Phase 1.5 – Using the Nokia IMPACT IoT platform to collect data and provide real-time dashboards to make the building's real-time energy status transparent.
- Phase 2 – Implementing automated video analysis and signaling to systems in order to make environmental adjustments, thereby eliminating the need for a person to monitor the system in addition to extending coverage to 24x7x365. (See Figure 5).

Figure 4. Phase 1 configuration

Energy information management system architecture
(Translated based on Ministry of Energy's Campus Energy Management Architecture)

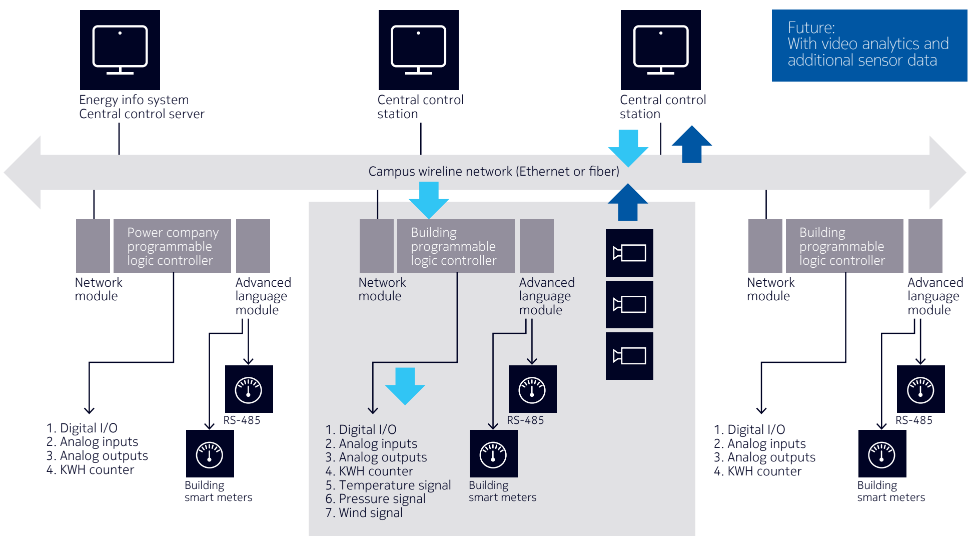
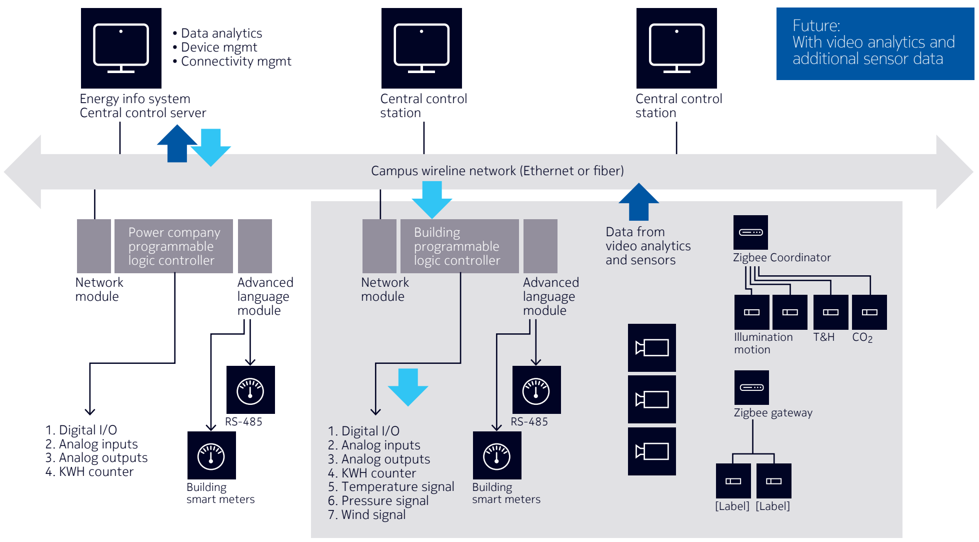


Figure 5. Phase 2 configuration

Energy information management system architecture
(Translated based on Ministry of Energy's Campus Energy Management Architecture)



Benefits

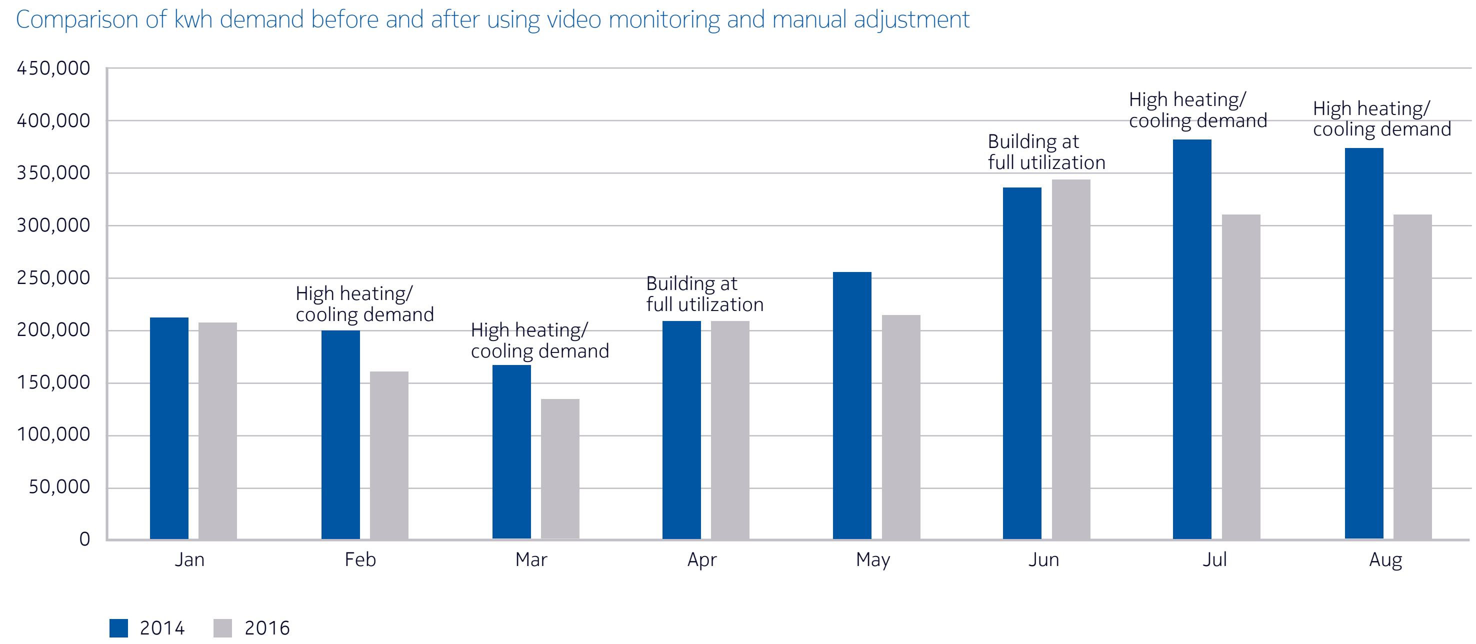
Phase 1 of this trial was completed to determine:

- Whether existing video cameras could be used to manually monitor traffic flow and the congregation of people in a building,
- To determine adjustments while maintaining the comfort level, and
- To reduce the use of energy to achieve cost savings.

Based on information from the university administration, the energy savings realized by using video surveillance to reduce unnecessary usage is about 11 percent.

A further examination of the building energy data between 2014 and 2016[3] shows that most of the other conditions have remained the same. The same air conditioning systems and lighting systems have been in use. Plus, the functions and activities supported by the building have not changed significantly.

Figure 6. Energy usage comparison of pre-market trial and Phase 1



Based on data comparing January to August usage in both 2014 and 2016, the total usage from January to August 2016 is 1,886,358 KW. For the same period in 2014, it is 2,132,027 KW—a difference of 245,669KW, or an 11.5 percent reduction. These savings can be justifiably attributed to video monitoring, as there have not been significant differences in the measures used to control the energy usage nor in the way the buildings were used.

Figure 6 compares energy usage in 2014 with no monitoring and adjustment to energy usage in 2016 with manual monitoring and adjustment.

3 Power usage and expenses of NCTU buildings. http://www.ga.nctu.edu.tw/ga5/energy.php?class_id=2

Observing this data, it is notable that, in high heating and cooling demand months, the Phase 1 implementation had the greatest impact. When the building was used most, the impact was negligable. Given that manual monitoring is in place during the highest building occupancy times, an opportunity exists for additional savings from automated monitoring in Phase 2 that would cover the 16:30 pm to 22:00 pm time slot uncovered in Phase 1. Another savings opportunity is expected when comfort sensors can be enabled in Phase 2. During Phase 1, there is also the possibility that not all savings were captured. This is because comfort thresholds may have been exceeded because they could not be measured. For these reasons, it is expected that Phase 1.5 and Phase 2 will yield additional energy and cost savings.

Summary

Partnering with Nokia through the ng Connect Program, NCTU has initiated the first phase of a Smart Campus initiative that consists of three main components: establishing a leading-edge network infrastructure on the campus; deploying an Internet of Things (IoT) platform that can be used to monitor and manage devices and IoT connections, as well as perform data collection and analytics functions.

At this point, the university has successfully completed Phase 1 testing of a smart building energy management system. During a six-month period, Phase 1 has shown energy savings of 11 percent and, with Phase 1.5 and 2 enhancements, the expectation is for additional energy and cost savings.[4]

What's next

As noted, Phase 1.5 will implement the Nokia IMPACT platform for tracking real-time energy usage. A dashboard of real-time measurements is expected to provide additional insights, as the effect of adjustments is immediately observable. With the introduction of IMPACT, Phase 2 will also add powerful analytics, as well as the ability to add and manage many devices and sensors. This is expected to bring more energy and cost savings. Once a positive business case is demonstrated, the same capabilities will then be rolled out to all buildings on campus.

During Phase 2, in addition to obtaining new sensor information from infrastructure changes, (including air conditioner units with newer technologies), the team will look for ways to optimize the balance between energy consumption and comfort.

This optimization task will include the creation of a model to calculate human comfort based on data from environmental sensors that will take into account temperature, humidity, and air flow speed. Multiple types of sensors will be installed to support not only energy usage control according to external criteria or policies, (for example, turning off the air conditioning when no one is present in a space), but also more importantly, to support the most effective energy usage to reach the optimal human experience. Achieving such a goal will likely require:

- Sensors to detect the physical environment and support energy usage control
- Sensors that support the simulation of human experience (NCTU has done research in this area), and
- Sensors on human bodies and in the physical environment working together to control energy usage.

4 The results of Phases 1.5 and 2 will be captured in updates to this case study.

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