Smart Camp

A Sustainable Digital Ecosystems Environment

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***Abstract*—Seamlessly integrating energy saving with the habits of daily life is an ambitious goal. It becomes even a bigger challenge in a remote area, like the Western-Australian Outback. Harsh environment, high temperatures and hard working conditions demand great exertion from humans and make one's well-being an integral part of life. To bring both together – environmental sustainability and life quality – is a new interdisciplinary approach in the field of computer science. A "Smart Camp" is a new low rate wireless personal area network (LR-WPAN)-based solution, which provides accommodations in a remote mining site with a smart automation and information system to contribute to environmental sustainability and to provide amenities for its inhabitants.**

The Smart Camp intends to monitor and control household appliances with the aim to reduce the overall energy consumption. Additionally, multi-media components will be implemented, which aim to make the occupants life more pleasant by adding value to their habitat.

Keywords: Smart Camp; Environmental Sustainability; Smart Home; Remote Areas; ZigBee Wireless Networks; Convergent Media; Quality of Life; Well-Being

I. Introduction

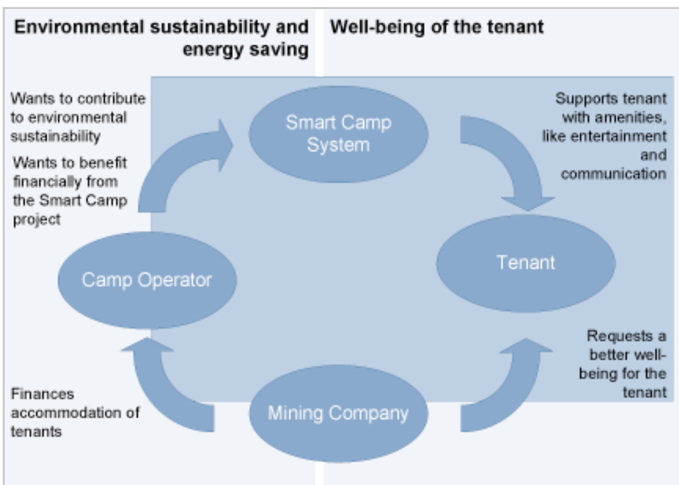
In recent years many new technologies have been evolved to contribute to a sustainable environment and energy efficiency. Rising prices for energy are continuously and environmental concerns like global warming and the carbon footprint are major topics in societies. Not only governments, but also organizations and private households need to be considered, to contribute to environmental sustainability. In this paper the terms sustainability or sustainable development will be used according to the 1987 Brundtland Report of the World Commission on Environment and Development [1] as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This is not limited to, but implies that it is necessary to increase the efficiency of the energy consumption to reduce the environmental impact.

In this paper we concentrate mainly on two types of technologies which are used to achieve two kinds of goals. Firstly LR-WPANs can be used together with logic units to monitor and control a household's power consumption. Secondly convergent multimedia devices can help us to obtain an improved well-being for the users. Merging these two goals will achieve a human- and environmental-centred home.

II. Overall Scenario

The Smart Camp project is a real world research project which is carried out by the Digital Ecosystems and Business Intelligence Institute (DEBII) of the Curtin University of Technology in Perth, Western Australia (WA). A real camp site, which is located in a remote area in the WA Outback, is used as a ground line for requirements and specifications of the Smart Camp project.

The challenges for the Smart Camp are unique as there are not only human requirements (in terms of one's well-being) but also industrial requirements. On top of this, the remote



situation and the harsh environment define further obstacles. It is likely that a growing number [2] of workers is needed to operate in these remote areas.

This illustration summarizes the overall scenario, which shows the two dependencies of the Smart Camp philosophy and the related parties.

Habitat: The habitat defines the real environment setting as it is given. The remote camp is located close to a mining site and provides accommodation to the workers. Every person is housed in a so called Single Person Quarter (SPQ) unit. These units only provide essentials like bed, bathroom and television. All units are also fitted with air conditioners (A/C) and electrical hot water pumps and are powered whether by the local grid or camp-owned diesel generators.

Tenants: The tenants of the remote camp are workers in a mining facility. The working conditions in such an environment are very special and the schedule for the workers is tight. Most of the labour work throughout the weekends and approximately from 5am to 5pm including breaks. A usual duty roster of the labour is e.g. 3 weeks on-site and one week off-site. Due to the remote area; long distance commuting is performed by fly-in, fly-out operations. One of the private issues for the labour is the boredom, as there is a lack of free time activities. Another issue is the social isolation especially from their families and friends.

Camp Operator: The camp operator's intension is to reduce the energy consumption to achieve a more environmentally sustainable camp management and financial savings. As the retention of the labour can be as low as 3 weeks, which is mostly a result of the hard working conditions, the hot weather, on-site boredom and social isolation, the well being has to be improved. Therefore a technical solution is needed which deals with the factors mentioned above. Additionally a security system has to be developed. Until now there is for example a manual key management for the 1500 SPQ units. A more sophisticated solution with access management for cleaners and technical operators is needed.

Mining Company: The mining company finances the labour's accommodation. The companies are interested to keep their staff motivated and to achieve higher retention rates.

Smart Camp system: The Smart Camp system will integrate different technologies to achieve the camp operators', tenants' and mining companies' goals. A system has to be developed, according to the given circumstances formed by the habitat.

III. Related Work

In interdisciplinary projects, like the Smart Camp project, different scientific fields contribute to a successful implementation.

For the purpose of this paper, the work in environmental sustainability can be divided into two focuses. One emphasises mainly on technological aspects [3] [4] [5], the other one considers human and psychological aspects [6] [7] [8].

In terms of technology, the rise of wireless sensor networks such as LR-WPAN found great attention in the field of smart appliances and in actual scientific and industrial projects [9] [10] [16] [17] [13] [14] [15]. Smart homes or smart technologies in general commit to contribute to energy savings in a special manner. Whilst energy efficient devices simply use less energy, smart technologies instead help to decrease energy costs of various kinds of devices and appliances, as they can be monitored and controlled remotely. This allows identifying lavish energy consumers in real-time and to develop a strategy, how to deal with those appliances to reduce energy consumption in a sustained fashion.

IV. Project Requirements

According to the allover scenario, mentioned above we define the requirements for this project. In order to reach the goals for the Smart Camp project we break down the requirements into four categories:

A. Real world requirements
B. Environmental requirements
C. Tenants amenity requirements
D. Security requirements

Interviews with the camps' management have been conducted and a site visit has been performed to prove the following requirements.

A. Real world requirements:

Those requirements relate to the industrial setup and the camp site habitat.

- Energy usage and cost reduction: the system has to contribute to energy saving. Energy costs should be reduced by thirty per cent.

- Camp Site Energy Control: to measure energy consumption, the total power consumption of the camp site will be monitored in real-time.

- Cost effectiveness; the suggested solution should return on investment (ROI) after 2 years.

- Occupant compliance: to run the system efficiently, it should be highly accepted by the tenants.

B. Environmental requirements:

- Environment effects system: Harsh, remote environment demands a system which fits to that need.

- System effects environment: Energy saving and environmental sustainability due to reduce the total diesel / grid power consumption and CO2 emission as a consequence.

- Awareness of the personal energy consumption has to be generated and knowledge how to reduce this consumption has to be transferred.

C. Tenants amenity requirements

- Protect trustworthiness and controllability of the system: the tenants should be able to control and regulate functions like their room temperature individually.

- The system must not be obtrusive or disturbing in everyday life situations.

- On-site boredom of the labour has to be minimized to increase the overall well-being of the tenants.

- Due to long distance commuting social isolation and loneliness on the camp site has to be minimized.

- Ease of Use; tenants should experience the system as usable. They should be able to operate the system without deep technical skills and with their own technical devices (e.g. smart phones) if desired.

D. Security requirements

- An agile access management system is needed, which has to be smoothly integrated in the duty and occupancy roster of the tenants, the facility management and service workers.

- Camp Site Monitoring; enhanced security due to the real-time monitoring of occupancy for each SPQ unit.

- Supersede present key hooks with an up-to-date smart-managed access system.

- The access system must include different profiles with different rights.

V. ARCHITECTURE

As outlined above, the system has to meet certain requirements. Our approach is based on different modular system components that will be seamlessly integrated into a Smart Camp.

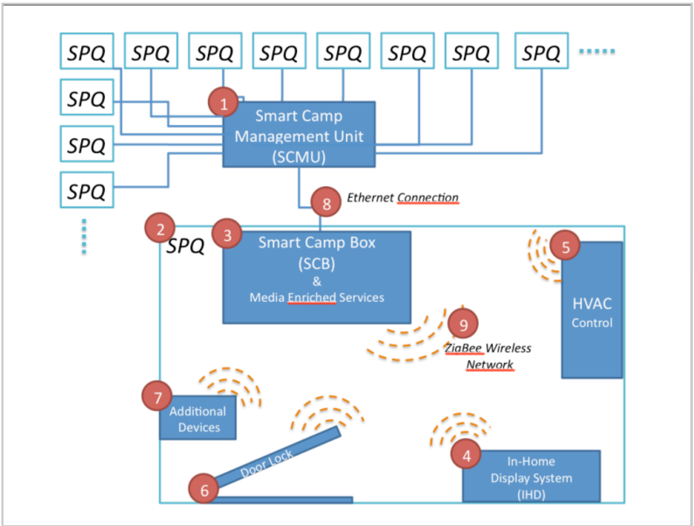


Figure 2. Smart Camp Architecture and Infrastructure

A. System Components

- Smart Camp Management Unit (SCMU) – The SCMU can be described as the control centre. It is a scalable application which remotely manages one or more camps and it is administrated by a security camp operator. The SCMU is considered to be the backbone of the entire solution. It gathers data from all of the Smart Camp Boxes (SCBs) to monitor different kinds of activities including power consumption and occupancy status of the SPQ units.

- SPQ unit – The Single Person Quarter unit denotes the accommodation for the labour. The main energy consumer in each SPQ is considered to be the air condition (A/C), which causes approx. 80% to 90% of the power consumption.

- Smart Camp Box (SCB) – The SCB is the central controller for the single SPQ units. It has an integrated LRWPAN Gateway and communicates to all other devices in the household. Therefore, it sends and receives messages from and to all other LRWPAN devices. It also inherits the media-enriched services: The SCB provides internet and VoIP-Services to the tenants via Ethernet cabling. The Ethernet connection is also used to communicate to the SCMU.

- In-Home Display (IHD) – The IHD will be located in a prominent position to make it an interactive feature of the household. The IHD shows the current power usage and the costs for the SPQ unit. The aim of the display is to motivate the occupants to save energy by giving incentives for acting responsibly.

- Heating Ventilation Air Conditioner (HVAC) Control – The HVAC control is also connected to the SCB via a LR-WPAN. It communicates bi-directionally and thus is able to read status information and send control commands. The SCB collects the data and automatically decreases the temperature or turns the A/C off, when the SPQ unit is unattended for a certain amount of time.

- Door Lock – The proposed door lock system will be using a wireless authentication system and the LR-WPAN interface for advanced control. The SCB keeps track of all access activities. Malfunctions will be forwarded from the Door Lock to the SCB; and from the SCB to the SCMU, where a camp operator keeps track of all requests and alerts.

- Scalability – The solution must be scalable and easily modifiable. Additional Appliances and sensors can seamlessly join the LR-WPAN.

B. *Functionality of the proposed solution*

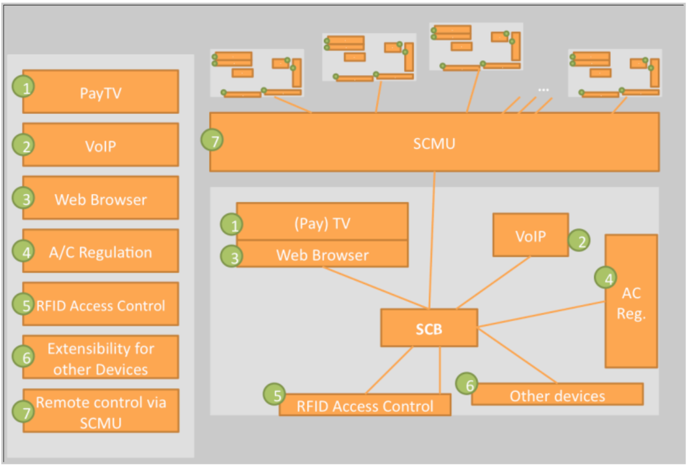


Figure 3.Smart Camp Architecture and Functionality

The above architecture can also be summarized by the provided functionalities (figure 2). (1) to (6) show the functionalities that are inherit by the SCB. It includes (1) Media on Demand (MoD), (2) VoIP, (3) Web Browser, (4) A/C regulation, (5) RFID access control and the extensibility for other devices. (7) The SCMU has the ability to remotely monitor and control the Smart Camp.

VI. COMPONENTS AND INFRASTRUCTURE IMPLEMENTATION

A. *The IEEE802.15.4 Standard*

As an implementation of the LR-WPAN the ZigBee Protocol has been chosen. It is based on the underlying radio standard IEEE802.15.4 for wireless communication (established by the Institute for Electronic Engineers, IEEE). All of these applications involve a central coordinator, also known as PAN (Personal Area Network)-coordinator. Two PHY layers are defined by the IEEE 802.15.4 which represents three license-free frequency bands that include sixteen channels at 2.4 GHz in Australia [16]. The standard is specified for communication in a point-to-point or a point-to-multipoint configuration with sleeping and security functions as integral parts of the standard [9]. For the set up of a personal area network (PAN), the IEEE802.15.4 standard allows the arrangement of two different types of network topologies.

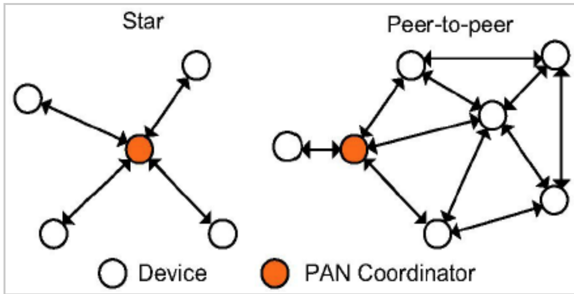


Figure 4. PAN Topologies [17]

Network devices can communicate to others on the network in its range using a Peer-to-peer topology. In this case, the PAN coordinator acts like a root of this network.

Both PAN topology settings will be tested, when the Smart Camp prototype is set up, to evaluate the best outcome [17].

The Physical (PHY) layer of IEEE802.15.4 provides four main functions:

- Spreading and de-spreading
- Modulation and demodulation of the signal
- Capability of measuring the power of the received signal
- Adjusting the connection quality

Direct Sequence Spread Spectrum (DSSS) is used as spreading technique in IEEE802.15.4. As modulation type in the 2.4 GHz band O-QPS with a 32 PN-code length and a RF bandwidth of 2 MHz is used. BPSK modulation with a 15 PN-code length is used in the sub-1 GHz bands and it operates in the 600 KHz RF bandwidth [16]. The MAC Layer offers seven main functions:

- Control to the access of the communication channel
- Flow control through acknowledgements and retrans-missions
- Responsibility for data validation and synchronisation
- Packaging of data into frames before transmission
- Unpacking frames and checking errors
- Providing service to the upper layers
- Monitoring of the channels through the use of CSMA/CA algorithm [17].

B. The ZigBee Protocol

The ZigBee protocol is a product of the ZigBee Alliance The Zigbee Alliance is an industry group that supervises the development of the standard. It focuses on the standardization of Low Rate Wireless Personal Area Networks (LR-WPAN) technology for applications in the industrial settings, building automation, and consumer markets as well as on the certification of products and brands compliant with the ZigBee standard. By defining the upper layers of the protocol stack, the Alliance is aiming to create secure, multi-hop LR-WPAN networks and interoperable applications [9].

The central concept of the ZigBee Application Layer is the Application Profile. Profiles are the key to communicating between devices on a ZigBee network. The Application Profiles define the devices, messages, and processing actions that comprise of an application running among ZigBee End Devices in a given environment in order to ensure compatibility and interoperable functionality between them.

C. Recent Research on the ZigBee Protocol

The sources [9] [18] focus on the implementation of ZigBee Wireless Networks, interoperability between ZigBee devices and how to integrate ZigBee networks into others e.g. for remote monitoring. As critical building automation applications, like surveillance and door lock systems, requires end-to-end Quality of Service, source [18] proposes a system architecture which is capable of dealing with the stringent and often conflicting requirements for wireless building automation by combining heterogeneous technologies into a suitable networking solution. Source [9] suggests a ZigBee-based Radio-Frequency Identification (RFID) Network, which is used for real time monitoring and locating objects.

Considering how the technology can interact seamlessly with consumer attendance and behavior, source [10] proposes an indoor positioning system via ZigBee devices. Another approach, shown by source [19] presents a solution, using an array of pyroelectric infrared sensors (PIR sensors), that are able to detect residents.

D. Energy Measurement and Awareness

There are different approaches on how to monitor, measure and display the power consumption of a household to its inhabitants. Source [20] shows that the approach of In-Home Displays (IHD) can achieve consumption savings of 5–15 per cent if they are part of a wider plan to save household resources. Based on evidence from existing Australian trials, they also found, that electricity savings of up to four per cent are likely through an IHD, without any other implementations. Source [8] states that it is useful to households to have a feedback information, which is specific to them and allows them to control their energy use more effectively. Therefore, mature key-drivers for the design of a IHD are user-friendliness, the display of instantaneous usage, expenditure and historic feedback as a minimum and also the potential for displaying information on microgeneration, tariffs and carbon emissions.

VII. Human Considerations

The three overall goals of the project are to decrease the energy costs of the remote camp, establish a security solution and to increase the amenity of the labour force. This assumes that the amenity will not be affected by the savings, which could usually be expected [11].

Source [12] describes reducing a household's energy consumption in general through two actions. These can be distinguished in two categories:

- **Technical Actions -** Technical actions require in the most cases a certain amount of investment. After the initial period of implementing energy-friendly devices a more efficient operation can save money. In our case the technological components have been mentioned above.

- **Behavioural Actions -** As [11] points out, behavioural actions don't need initial financial investment but require personal knowledge and efforts to reach the goal of saving energy. There are two main factors making energy saving hard for the Smart Camp project: Working on a remote camp means to have to deal with given working hours [22] and being isolated from relatives and the social home network. We assume that the employees work is quite tiring and many workers may not be willing to spend additional efforts on saving energy at the camp. Another reason might be the lack of information for the workers. There might be no knowledge about how to save energy. Secondly, in such Outback camps energy is partially or totally subsidized [22], to make a remote site more attractive for potential workers. The excessive energy consumption has no financial disadvantages; neither has the active saving of energy any financial or other gain.

In the recent years there has been a relatively young movement in the field of psychology, which tries to understand positive human factors and is an alternative way to psychology as a "victimology" [23]. In this work we are using the terms Quality of Life (QoL) and Well-Being for this purpose.

A. *Current Problems*

Social Isolation: To be isolated from family and friends can have a negative influence on ones well-being [24]. As [22] points out, moving to remote towns has several impacts on the workers' social life regarding their families, relatives or the social network of their home location in general [24]. This is the effect of either moving to a remote camp or commuting between a camp and the home location. The average retention of employees in a North-Western Australian mining camp can be as low as 3 weeks.

Boredom: Besides the social isolation boredom is a problem in remote camps. As the temperatures in summer are very high, outdoor activities may not always be pleasant or even possible and indoor activities might be limited through the isolated location of the camp. Indoor activities like watching television might be the most convenient after-work activity. However television seems to have rather a negative influence [25] on ones QoL. The reason for this is that it often doesn't contribute to the personal development, which is an important factor in QoL.

Adoption: As a third problem the willingness of adopting the system is an important factor, which is correlated with usability issues. The system has to be adopted and found usable by the inhabitants. Both factors can be seen as the basis to take effect on life quality and decreased energy costs.

The following table summarizes the human goals of the project:

TABLE I. SMART CAMP GOALS

Quality of Life Goals
Understand the actual every day flow of the workers.
The implementation should not affect the daily flow of the labour negatively and be adopted in a high degree.
Improve variety of possible indoor entertainment activities to reduce boredom.
Minimize the social isolation with a digital communication setup.

B. *Future Solutions*

Understanding the process of the workers daily life will help us implement a QoL supporting solution. Qualitative research will be done and workers will be interviewed.

There are different QoL approaches and methods of QoL measurement, depending on the contexts in which one wants to measure or get a better understanding for the situation. Therefore the concept of flow [26] will be used as a basis to get a understanding of the users and then to decide which measurement method fits best.

The influence of media on QoL, especially on television has been investigated. Csikszentmihalyi's flow theory [26], [25] can be used to show the impact of television and computer technology on the flow. Source [27] especially points out the negative influences of television, which is considered as flow-disturbing.

Life quality findings regarding internet technologies are more positive [27]. "They contribute to happiness to the extent that they provide opportunities for personal growth and development and provide the individual with greater stability and control over his or her environment. Enhancing the TV with new media services and communication systems will lead to a media-convergent system. The influence on QoL hast to be proved. The convergent solution will allow the user to access and control the media and smart services either from the TV Screen or personal devices like smart phones to achieve a truly Smart Camp.

VIII. CONCLUSIONS

This paper portrays two different dimensions of the Smart Camp project. It describes the development of a prototype for sustainable Smart Camp management. Underlying technological solutions, like the used ZigBee network and the system architecture are described as well as the work on understanding the human factors in such a project.

The Smart Camp is in its opening phase, the status quo has been described.

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