Individual status assessment using Wireless Body Area Networks

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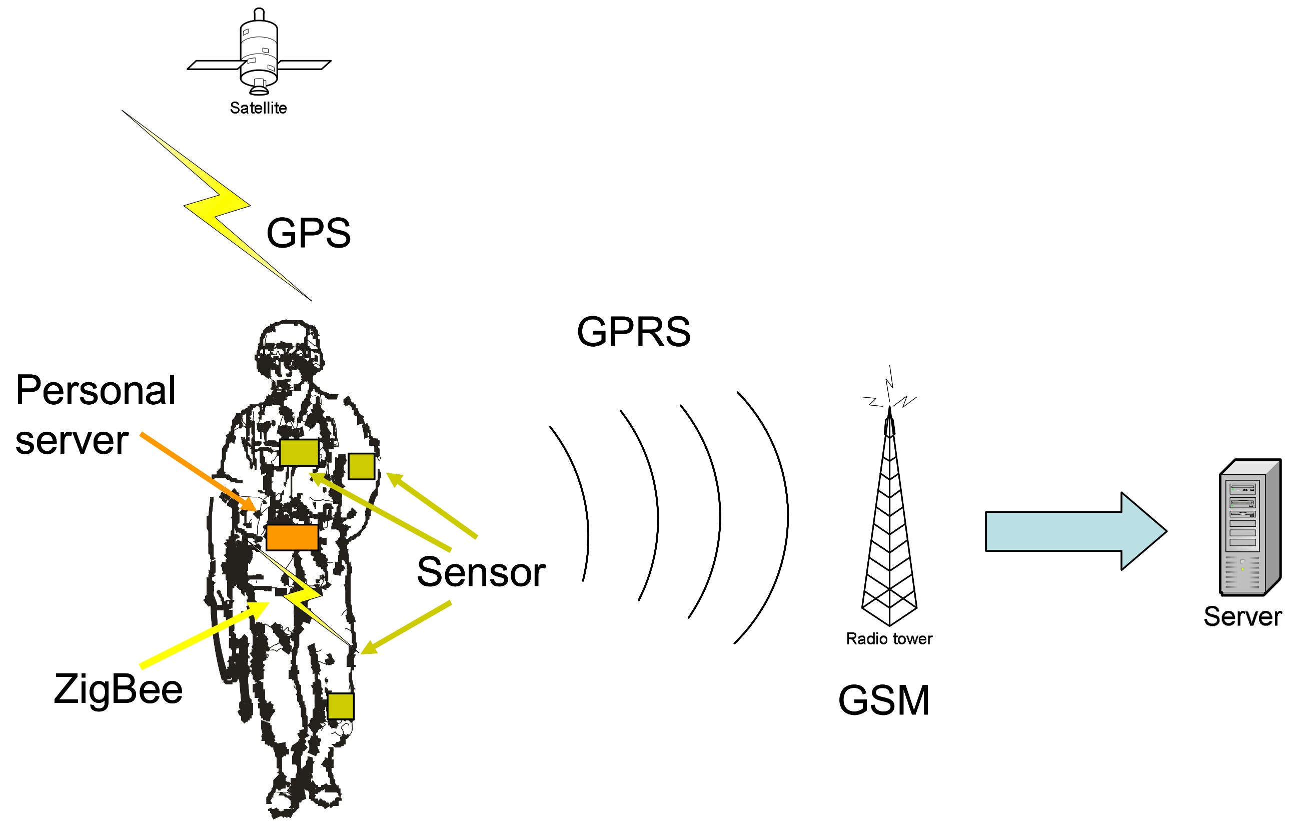

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Sammanfattning

Denna rapport är resultatet av det andra året av FoT-projektet *Tids-/resurskritisk ledning med övervakning av individstatus (TRIS)*. Syftet med projektet är att undersöka möjligheterna att utveckla ett systemkoncept för ett beslutsstödssystem för övervakning av individers status. Övervakningen är tänkt att ske genom insamling av fysiologisk- och psykofysiologisk information och olika former av omgivningsinformation. Systemet ska samla in, bearbeta, fusionera och visualisera denna information för att stötta användarens beslutsprocess. Projektet samarbetar med andra organisationer för att bidra till utvecklingen av ett test- och demonstrationssystem för detta ändamål.

En del av TRIS är det så kallade *wireless body area network (WBAN)* bestående av kroppsburna sensorer från vilka data trådlöst överförs till olika nivåer av beslutsfattare. TRIS ambition är att systemkonceptet ska vara flexibelt och att informationsinhämtningen kan anpassas till olika användares behov och roller.

En första utvärdering av WBAN konceptet har koncentrats till insamlade variabler, aspekter på dataöverföring och metoder för kommunikation. Ett flertal förbättringsförslag har identifierats. En angelägen systemegenskap är adaptivitet, dvs kommunikationen anpassas efter behov för att på så sätt öka effektiviteten i energianvändningen.

Nyckelord: Fysiologisk status, individstatus, WBAN, beslutsstöd, data fusion, övervakning.

Summary

This report is the result of the second year of the FoT-project *Time-/Resource Critical Command and Control with Monitoring of Status of Individuals (TRIS).* The purpose of the project is to determine the possibility of developing a system concept for a decision support system for monitoring status of individuals. The monitoring will be accomplished by collection of physiological- and psycho physiological data in combination with different forms of contextual information. The system will collect, compute, fuse and visualize this information to support the decision makers' decision process. The project is contributing to the development of a test- and demonstration system in cooperation with other organizations.

One component of TRIS is the so-called wireless body area network (WBAN) allowing data from sensors worn by the individual to be wirelessly transmitted to different levels of command and control centers. An ambition of TRIS is that the WBAN system concept shall be flexible and that the information collection shall be adaptable to accommodate for different users needs and roles.

Initial evaluation of the WBAN has concentrated on variables to be collected, aspects on data transfer, and methods of communication. Suggestions of improvements have been identified in various areas. One important aspect is adaptivity in data communication in order to increase energy efficiency.

Keywords: Physiological status, status of individuals, WBAN, decision support, data fusion, monitoring.

Innehållsförteckning

1 Introduction

This report is the result from the second year of the FoT research project *Time-/Resource Critical Command and Control with Monitoring of Status of Individuals (TRIS)* (Tids-/resurskritisk ledning med övervakning av individstatus).

1.1 The TRIS project

The TRIS project runs over three years ending in 2010. The purpose of the project is to investigate the possibilities of developing a system concept for a decision support system for monitoring of individual status. The realization of the monitoring system is anticipated to be based on collection of physiological and psycho-physiological data, contextual information, and observation reports from field observers. The system will acquire, reduce, fuse and visualize this information in order to support the users' decision making process. Relevant status information shall be readily available to the operators' according to their specific needs and requests. Examples of typical users of the system are commanders in military and civil emergency management. The military application of the system is concerned with the monitoring of status of soldiers before, during and after missions. A military commander shall be able to assess if the task is conducted according to plan with respect to the soldiers physical and psychological load, movement velocity, injury status, etc. Automatic alarms shall relieve the user from the continuous monitoring task.

The project is cooperating with other organizations and internal FOI projects in developing a prototype system for experimentation and demonstration. This system will be used for a feasibility study in which the options for realization of a decision support system for monitoring of individual status are studied.

1.2 TRIS general idea

Physiological and psycho physiological monitoring can be of interest for various types of applications regarding health and safety such as: military operations, first responders, rescue operations, medical supervision, and home care.

The ability to supervise training, including physically challenging exercises, and the effects of training is another interesting area of application. This includes study of task performance, determination of individual readiness, evaluation of progress in sports/athletes, and rehabilitation.

Detailed individual physiological and psychophysiological monitoring in real-time requires a dedicated data acquisition system and means to transfer data into existing command and control facilities. The proposed realization is to use body worn sensors connected to a wireless body area network (WBAN) for collection of the desired data from an individual. The data is processed locally before being transmitted to a remote computer central for further analysis and visualization. In addition to actual monitoring, such a system could be used for after action review and training.

Although the basic system concept can be generalized and pertain to a number of different types of application as mentioned above this system is designed with the military application of health and safety in mind.

In the overall concept an information system gathers necessary data from multiple and available media sources and databases, as depicted in Figure 1. Data fusion methods are used to obtain the appropriate aggregation for decision making purposes.

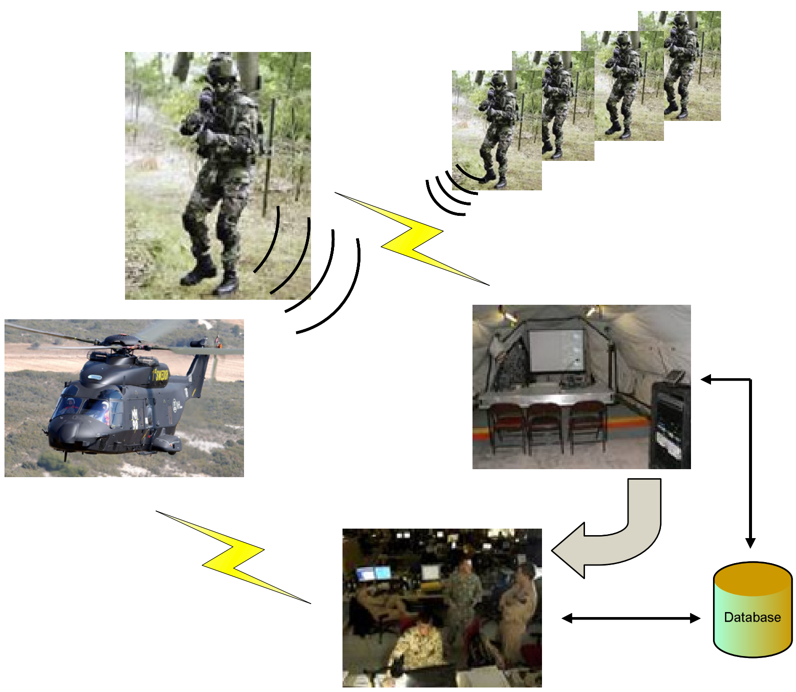

Figure 1. A graphic representation of the general concept.

2 Individual status assessment

The intention of every military operation is to succeed in reaching the declared objectives. The probability of success, however, will most likely depend on a number of different factors or prerequisites. It is necessary to have adequate resources in the form of personnel and materiel, information and support systems. These resources have to be tailored to the specific type of mission and environmental conditions.

Today the result of a mission may depend on the performance of single units and hence a single soldier. The commander needs to know how he can utilize his resources, i.e. he needs information on the individual/group readiness levels. Which group has the required skills? Are they prepared for this task? Have they recovered from their last operation? The readiness level of the resource before the start of the mission needs to be determined on beforehand to enable the commander to utilize his resources optimally

While engaged in theater, the individual or team may be exposed to hostile environments and numerous types of threats causing high and constant stress levels. These engagements sometimes lead to combat situations and result in a range of injuries. During these circumstances the commander is expected to benefit from frequent updates of readiness levels of his subordinates.

The ability to assess performance and readiness is a function of data availability and methods of data processing. Recent technological development is bringing new possibilities into this field of application. New smaller and less energy consuming sensors and data systems can provide continuous streams of data to command and control centers. Future technology is expected to provide means for advanced supervision of individual or team positions and their wellbeing during operations.

Upon completion of the assignment the troops normally return home, revert to normal service duties and begin reacclimatizing to a civilian life. Post mission debriefing and health monitoring can aid in the determination of specific individual needs for treatment. Lessons learned on all service levels should be compiled and used in education and training for future missions, for which this data acquisition and analysis may also be very useful.

At this point we can discern three different and important phases of activity; a) pre mission, b) during mission, and c) post mission. The activities in each phase will have strong effects on the others. It is a continuous circle of events as shown in Figure 2.

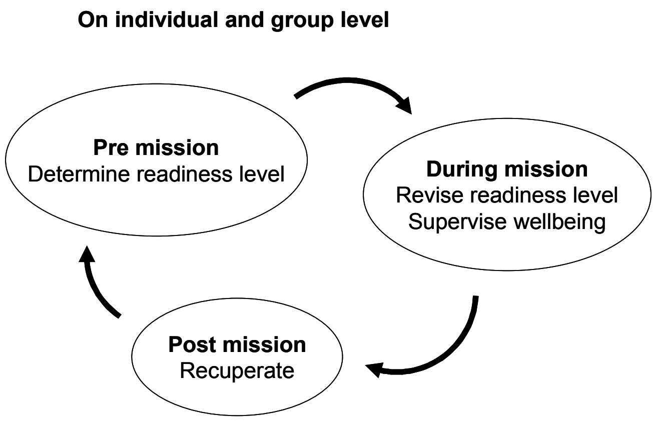

Figure 2. The three mission phases.

2.1 Pre mission activities

This is a subset of important activities in the pre mission phase and the associated research applications presented on a high level.

Selection

- Find suitable personnel

Education

- Particulars of the environment on site
- Cultural awareness, learn about the culture on site
- Learn how to communicate with the local population

Training

- Physical training, basic training
- Physical training, mission specific
- Development of individual task specific skills

Technical preparations

- Acquire adequate equipment

Evaluation

- Determine predicted readiness level

It is reasonable to assume that the selection methods used today can be improved to increase the likelihood of mission success. Assuming this selection process can be aided by health-related data acquisition, exactly which variables are to be measured and how to set up optimal selection criteria is still to be researched.

Education and training includes skill acquisition in several areas. It is of interest to determine performance increase as an effect of training and education and also to identify factors associated with good performance.

The materiel to be used is critical for mission success and must be scientifically evaluated prior to the missions in order to optimize utilization of equipment and increase the endurance. Hence, performance and outcome of an operation is a combination of individual/team skills and abilities and the materiel/support available.

2.2 During mission activities

The mission per se is affecting the personnel in various areas, some of them are physical and others are psychological. Their gathered experiences and exposures will affect the performance and readiness levels continuously.

2.2.1 Real-time status monitoring

Real-time systems for monitoring the status of individuals and groups are useful in many situations and for various reasons. In particular, monitoring of physiological status is important when individuals are engaged in high risk operations e.g. for military personnel or responders to crises and emergencies. The data obtained from such systems can prove both high and low levels of assessment of the actors' physiological and psychophysiological status. These aggregated data support commanders and group leaders in management of the operations as illustrated in Figure 3. Easy to interpret graphical displays in command and control centers augments the commanders' situation awareness.

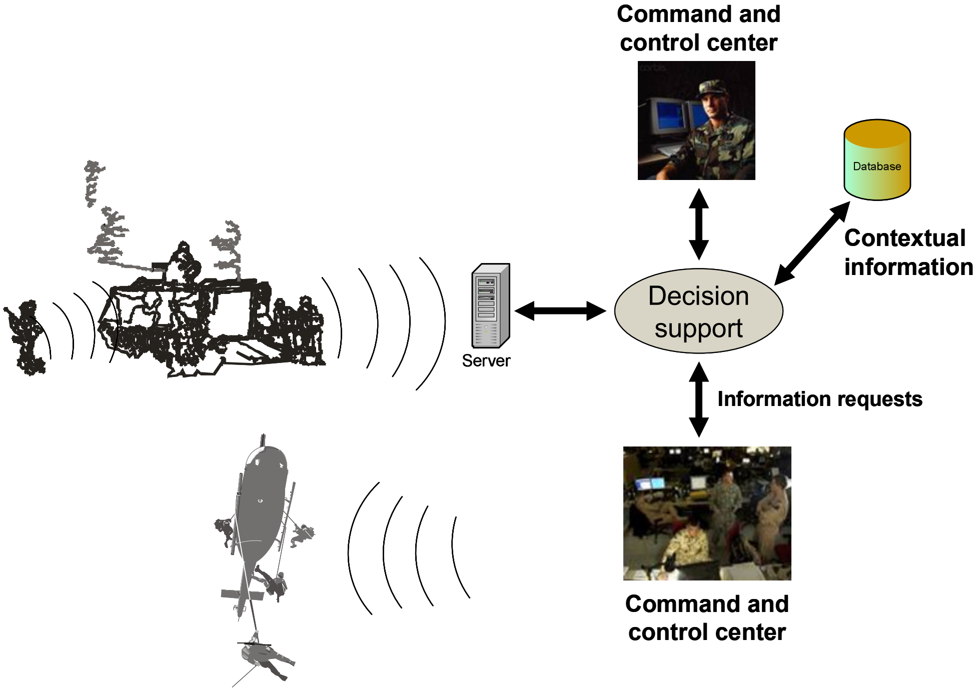

Figure 3. The overall monitoring concept

There are a number of variables that theoretically could be measured objectively and automatically. Some type of data, such as weather, could be made available from common resources, while others need to be gathered from a person through a portable data acquisition system. Still there is information that probably needs to be inserted manually. Personal ratings and assessments are valuable subjective measures and could be added, if not in real time, during post action review. Figure 4 shows a number of variables and factors likely to affect the personal wellbeing and hence readiness and performance.

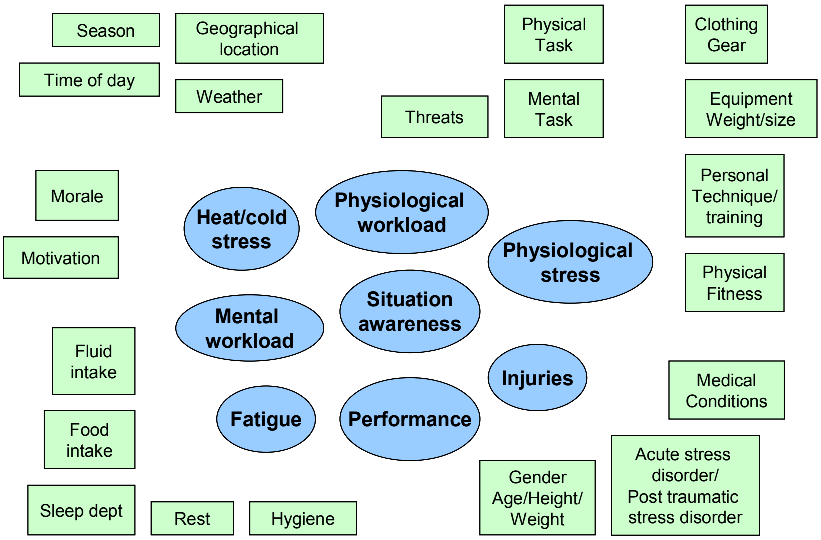

Figure 4. Variables and factors affecting individual status

Individual physiological and psycho physiological monitoring can be used for health and safety monitoring, medical emergencies, physically challenging exercises, and to study task performance.

Data from actors is gathered from multiple sources. An information system gathers data from sensors and use data fusion to obtain the appropriate aggregation for decision making purposes.

The ability to assess performance and readiness is a function of available source data and methods of data processing. The quality of data is an issue; the system must be able to work with temporary loss of data and times of data with poor quality. Individual status modeling and assessment is the project objective. Some of the questions that this project intends to approach during 2010 are: How much data do we need? How much data can we expect to get? What is our modeling approach to fuse and analyze data automatically? How should we handle effects of context? How can this data help in determination of readiness on individual and group level?

2.2.2 After action review

After action review is a formalized method for evaluation of exercises and operations. It has a psychological importance in avoidance of acute psychological stress reactions. An FOI in-house developed framework called F-REX, Figure 5, supports this type of procedure through introduction of reconstruction and exploration. F-REX allows after-action reviews by enabling visualization of any data type in a chronological order and related to other data sources, giving the analysts the opportunity to quickly get an understanding of the data being observed in relationship to the context in which it was sampled. The system visualizes and plays back concurrent data from several data sources dispatched over a large area enabling the users to quickly get an overview of the current situation at different locations and thus get a relevant context for the analyses.

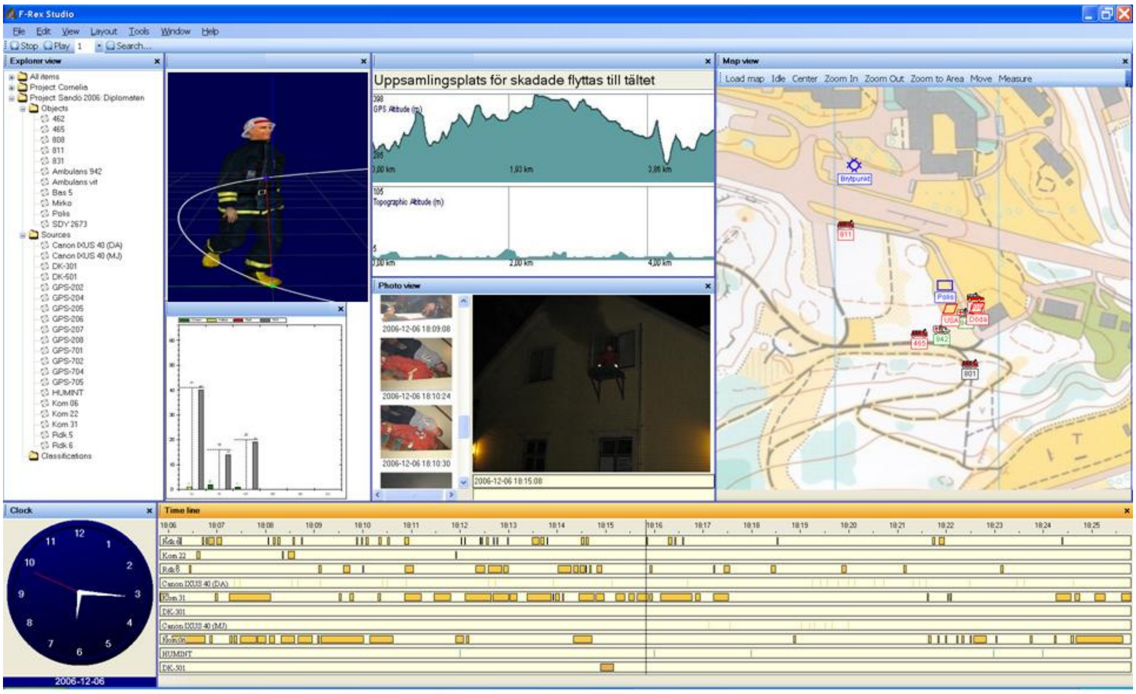

Figure 5. Example of synchronized visualization of sampled data and multimedia information for contextual analysis in F-REX Studio.

The layout in Figure 5 displays a priori information, timeline, photos, video, map with GPS tracks, heart rate, altitude, stance and statistical metrics. This tool is well-suited for post action analysis of data being gathered by an individual monitoring system.

Extensions to include online visualization of data in F-REX are in progress. This will allow the system to be used both as a real time evaluation tool and for development of concepts for decision support. Currently, F-REX is able to simultaneously monitor and record audio, video and text streams as well as GPS positions, using the well-known RTP protocol for transferring data in real-time over UDP/IP. Modifications are under development to visualize heart rate, temperature and body posture, using the input data from the WBAN prototype system described in this report. Further modifications to reduce the risk of information overflow are also anticipated, both by using local data fusion before sending data to F-REX and by using advanced information visualization techniques in the F-REX system itself.

2.3 Post mission activities

Post mission phase takes place off theater and often receives little focus. However this phase is important from a number of aspects. It is an ideal opportunity to gather experiences from action; review and discuss these new experiences and to draw conclusions. Lessons learned in one mission could be important for future missions in order to be better prepared for similar incidents. It can also be important from a psychological point of view in order to detect tendencies of post traumatic stress disorder.

3 System requirements

The purpose of the system is to provide appropriate information at various levels of interest. The complete chain from remote data collection to presentation at end user location can be divided into four major processes; data acquisition, communication, analysis, and presentation. All four processes has previously been investigated with respect of user needs, system concept, system requirements, collected variables, communication methods and decision support system needs. The results are presented in recent reports Lantz, et. al, 2008] and [Lantz, et. al, 2007].

Solving present challenges in adverse environments is expected to satisfy most needs in the less complicated areas.

3.1 Collected variables

Continuous supervision of human physiological status requires a set of sensors capable of detecting variables of interest. Health and safety monitoring might focus on observations of one or more critical variable, such as the heart activity in a patient with diagnosed heart failure or the potentially fatal heat stress for a fire fighter. For a medical emergency it is important to use sensors capable of detecting vital signs such as body temperature, respiration, heart rate, and blood pressure. In a physiologically strenuous situation in a hostile environment it may be relevant and feasible to measure body and ambient temperature, heart rate, perspiration, respiration, as well as altitude, position, and body posture. Determination of task performance often comprises both physiological measures of fitness as well as psycho physiological measures including subjective ratings, heart rate and heart rate variability indicating mental stress.

3.2 Hardware requirements

In order to assess physiological status the various variables need to be properly recorded and further processed. Remote data acquisition is accomplished using telemetry techniques allowing data from various sensors to be collected and transmitted at different rates.

Soldiers are often carrying heavy clothing and equipment, including body armor, weapons and combat bag. Naturally, the hardware units must be carefully designed to avoid considerably addition of carried weight and to minimize interference with the users' activities and their ability to move around freely.

Consequently, there are a number of different requirements posed on a WBAN system designed for motion in adverse environments. The hardware units should have the following properties:

- Minute size/volume
- Low weight
- Easy to use

It is also of interest that the sensors are able to operate continuously for days or maybe weeks in a row. Long duration exercises and difficult environments put additional and tough requirements on the sensors and the recording system such as:

- Sensors should be durable for tear and wear
- Low power consumption

Current technology offers systems that are useful for concept development, research, training and other applications not requiring extremely low weight etc. However, in order to entirely meet all system requirements and to obtain a fully functioning hardware solution need for further development have been identified in the following areas:

- Miniaturization, smaller flexible sensors and computational units
- Energy efficiency with respect of sensors, computational units, and transmission
- Energy scavenging

Basic research on energy scavenging has taken a broad approach and many concepts seem promising for the future. Local energy harvesting could replace the need for batteries in many applications. The necessary power could be generated for instance using solar panels, body/limb motion or body heat.

3.3 Data communication

Transmission of data generally consumes more energy than the computational effort involved in collecting the data. Most energy is therefore expected to be saved by minimizing the need for data transfer. One way of saving energy is to avoid unnecessary communication. It is therefore of interest to use two way communication with sensors/computational units to be able to request both different types of data and/or variable data update rates. This can be used in two ways, either speeding up the data rate or lowering it. For instance, normal update rate can be lowered when little of interest occurs and increased rapidly when deemed necessary either manually by the operator or automatically by system preset limits. For a soldier in distress an automatic alarm alerts the observer and immediately more data types and or data at higher rates is transmitted depending on system configuration and/or level of command and control. A typical example is heart activity; the normal variable transmitted could be heart rate while when so required the actual raw ECG data is included for medical judgment.

In order to further minimize the need for communication more computation could be made locally at lower levels, even at sensor levels. The data transmitted to the users would then be refined, fused and perhaps ready to be interpreted.

The general suitability of methods for data transfer and communication is an important research topic and a prerequisite for realization of on-line monitoring in the field. Naturally there are a number of issues involved in data security and personal integrity. Secure data transfer protocols is necessary in order to guarantee data integrity. Any fielded system would have to be authorized for use regarding data security.

3.4 Data analysis

The information system has to provide sufficient types of data and data update rates. On the other hand, vast amounts of source data is not appreciated at higher levels and necessary filtering and selection must take place. Various levels of command and control have different needs and the definition of the information to be presented is expected to be a delicate task.

An important system requirement is robustness; the real world environment is adverse and permanent or temporary loss of data is inevitable. Consequently, the information system must be able to handle loss of data and to identify data with poor quality.

Individual status modeling and assessment also requires context and background data. How much data do we need? How much data can we actually get? What should our modeling approach look like? How can this data help in determination of readiness on individual and group level? How can we handle effects of context? There are many questions that need to be answered; experimentation using a prototype data collection and data fusion system for individual health status monitoring is expected to shed some light in these areas of interest.

4 WBAN prototype system

A market inventory of systems for individual monitoring and data collection was conducted in the initial phase of this project; see [Lantz, et. al, 2007]. The review showed that most systems used wired transmission of sensor data to a central processing unit. True wireless systems, i.e. allowing the actual sensors to communicate wirelessly, were rare and limited in number of sensors used. However, this project was interested in a multiple sensor system and an opportunity to cooperate with WISENET was expected to be one step in the right direction of obtaining a feasible basic solution.

WISENET (Uppsala VINN Excellence Centre for Wireless Sensor Networks) is an excellence center with current partners from Upwis AB, Uppsala University, SICS, FOI and ten other organizations.

WISENET research is focused on how to:

- integrate sensing, data processing and communication into one sensor unit
- manage and generate energy in the sensor unit
- make sensor networks self-configuring, robust and maintenance-free up to 10 years
- attach sensors to Internet in a secure way, with the objective to reach an integration size of 5x5x5 mm and a manufacturing cost of 1€ for a regular unit.

A working prototype of a WBAN has been developed under the WISENET cooperation. This specific hard- and software platform called WIRP (WIreless Research Prototype) is all wireless and thus removes the need for cables. Today WIRP consists of sensors transmitting data to the so-called personal server (a central processing unit) using the ZigBee wireless protocol. The personal server in turn communicates with a server at FOI using GPRS as shown in Figure 6. Additional reading can be found in (Jobs, 2009) and (Bestoon, 2009).

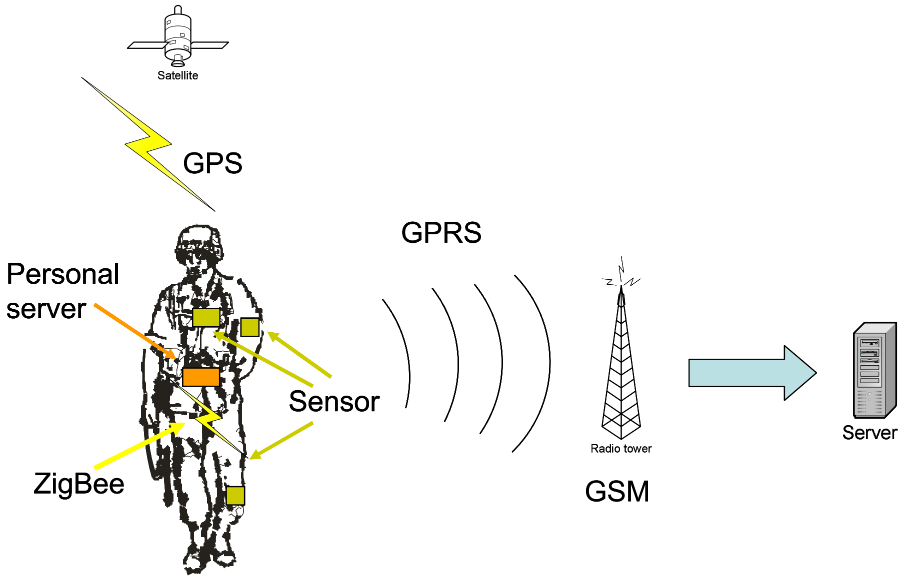

Figure 6. The WBAN concept

Data are transmitted wirelessly from the actors to the personal server where data are assembled and further transmitted to a decision support system where the information is further processed and visualized.

4.1 Communication

As mentioned above, all communication between sensors, the processing unit and the remote command central is wireless. The wireless sensors communicate with the personal server using the ZigBee protocol, effectively forming a wireless body area network (WBAN), while the personal server communicates with the command central using Internet via GPRS, creating a wide area network (WAN).

4.1.1 WBAN

A WBAN can be seen as a wireless personal network (WPAN) where all the devices are attached to the body. The specification for the WPAN standard should therefore be more than adequate for a WBAN, making the standard WPAN protocol implementations, such as ZigBee and Bluetooth, interesting for this application.

ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios conforming to the IEEE 802.15.4-2003 standard for WPAN. Bluetooth is another well-known standard for personal area wireless communication widely used in consumer electronics such as mobile phones. Compared to Bluetooth, ZigBee consumes less power which leads to an increased uptime for the system at the expense of lower data rates. The stated data rate of 250 kbps for ZigBee was estimated to be sufficient for the initial application and concept evaluation.

ZigBee has lower latency compared to Bluetooth, which makes the effective data rate better than for Bluetooth at a small packet size (up to approx 64 bytes) even though the maximum data rate is significantly lower [Kinney, 2003]. The ZigBee specification states a maximum operational range of 5-50 meters depending on the surrounding environment whereas Bluetooth is typically specified to have a maximum range of up to 10 meters for device class. Therefore range is not an issue in the choice between these protocols.

It should also be noted that other alternatives exist, such as ABB:s WISA, Wibree, Z-Wave, Wireless USB, UWB, EnOcean, 6loWPAN or ONE-NET. However, none of these have yet been investigated for this application.

Choosing ZigBee for the WPAN gives a theoretical addressing space of 64 bits, allowing more than 10^{19} nodes to be connected to the network. However, to reduce the overhead the addressing space can be shortened to 16 bits, allowing 65536 nodes in the network which is more than plenty for this application (Kinney, 2003). It also provides the ability to assign different address spaces for different systems permitting creation of sub-networks to avoid interference when two systems are within range of each other. A typical setup could use 8 bits for network identification and 8 bits for device addressing, rendering 256 separate systems each capable of connecting to 256 individual sensors. ZigBee also provides optional AES encryption [Daemen & Rijmen, 2002] to support data confidentiality and integrity; this has not been implemented in the prototype system.

4.1.2 WAN

General packet radio service (GPRS) is a packet oriented mobile data service available developed to support data communication in the second generation mobile telephone system, GSM. A GPRS device typically connects to the Internet service provider (ISP) gateway via the telephone network and can transfer data at a rate of 56 up to 114 kbps via GSM. Using 3G technology this speed can be significantly increased, however at the expense of higher energy consumption.

GPRS communication is used in WIRP to communicate data from the personal server to a server at FOI, creating a wide-area network (WAN) between the two. GPRS has been chosen since the existing infrastructure provides good coverage in Sweden. Alternatives to GPRS via GSM include utilizing the 3G and the future 4G networks or falling back to the old NMT network which now is operated by ICE.net to provide low cost Wireless Internet connection in less inhabited areas where NMT network coverage is typically very good. It has also been recognized that Internet may not be appropriate at all as a medium of transporting the data to the remote command and control centers in all cases, in these scenarios separate radio networks will have to be used depending on the users' needs. In order to reduce the risk of data intrusion and theft in this prototype system, all information being sent over the Internet is encrypted through use of a secure shell (SSH) tunnel.

The currently selected solution is the lowest cost solution in terms of both energy consumption and price as far as our investigation has shown. A more thorough investigation of the different alternatives and a cost-benefit analysis is required to give a proper answer to whether or not this is in fact the optimal solution. However, for this prototype GSM GPRS has been judged good enough.

A consideration to keep in mind with this solution is the fact that most GPRS ISP:s will not automatically give the connecting client device a public IP address, meaning that the remote command and control center will not be able to push data to the personal server because it won't be able to address it. Instead, the personal server needs to contact the remote server and poll for new requests if two-way communication is needed, introducing a slight latency in the communication depending on the poll interval. It should be noted though that even with special accounts that allow static public IP:s, it is still not desirable to keep an open connection from the GPRS device to the ISP as this would cost a lot of energy.

Currently, only one-way communication is implemented in WIRP, however, two-way communication is on the agenda for 2010 where polling is expected to be implemented and optimized to find a good balance between latency and energy consumption.

Although communication over GSM GPRS is cheap in terms of energy consumption compared to most other long range communication alternatives, it is still very expensive in relation to the basic processing time on the personal server. Therefore the personal server should have routines for pre-processing of data and in order to transmit a minimal and adequate amount of data necessary to perform operator assigned duties. Rudimentary implementations exist today, but how to perform this act of balance optimally is still being researched.

4.2 Sensors

Implemented sensors consist of 3-axis accelerometers, thermometers, and a GPS receiver. These sensors provide direct information on a person's location and body posture. The data analysis process including data fusion is expected to provide additional information such as type of motion and activity performed.

4.2.1 Accelerometer data

Each accelerometer sensor has 3 axes, X-Axis, Y-Axis, and Z-Axis. The sensors are configured to send one package of data every 20 seconds, where each package contains 10 samples per second per axis of the accelerometer. The 10 Hz sample rate is expected to be sufficient in order to detect body motion states and will significantly reduce the power consumption. However, the sensor firmware is constructed to be able to send up to 200 samples per second and high data rates provides ability to detect high frequency events such as the impact associated with foot steps or a person falling to the ground.

4.2.2 Temperature data

Temperature is measured using negative temperature coefficient (NTC) thermistors. A thermistor is an electronic component that converts changes in temperature to changes in resistance. Although the thermistors are measuring temperature these sensors are not adequate in the current configuration for actual measurement of body skin temperature.

4.2.3 GPS data

Outdoor positioning is implemented using a GPS Receiver Module integrated with the personal server. The GPS receiver provides regular GPS positioning data and the GPS time is also used to timestamp incoming data from the sensors in the WBAN.

The GPS unit will not be completely operational in certain environments, such as indoors. Alternative positioning based on inertia is currently under development at other FOI projects and may become integrated into the system at a later stage.

4.2.4 Sensor data transfer

Transmission of data from the sensors to the personal server is implemented using ZigBee as explained above. The current status of the system shows some abnormalities with unforeseen data loss. Although packet loss is expected in wireless communication, a ratio of 5% data loss seems a bit high.The reason for, and implication of, this is currently undergoing research. Initial investigations have shown that data loss may correlate to the sensors' relative positions to the body and the personal server. Exactly how this will affect the performance of the end system remains to be investigated. Some potential for improvements in design of sensor boards and firmware which could lead to slightly higher throughput has been identified.

When each package is transmitted the sensor data recording is suspended due to the lack of multi-threading, causing a periodic data loss in the current implementation, averaging of about 91 ms in length. The periodic data loss may cause a significant noise affecting analysis of the sensor data. A new multi-threaded version of the software that allows for parallel data collection and transmission is currently under development. This new version is expected to solve the problem of periodic data loss due to transmission.

5 Conclusions and future work

The TRIS project has previously identified a number of research questions regarding data such as access, availability, quality, and security. Another subject is alternatives in data transfer concerning power consumption and amounts of data transmitted. The initial evaluation of WIRP has shown that it is possible to design a system based on multiple wireless sensors. Some areas of improvement and further development have been identified as the evaluation continues into the next more experimental oriented phase.

5.1 Radio based applications

The WIRP application described in this report relates to individual status monitoring based on GPRS for WAN communication. The feasibility of using Internet and mobile communication per se is discussed in paragraph 4.1.2.

Soldiers are often operating using vehicles, such as combat vehicles, providing radio communication with command and control centers as shown in Figure 7. Vehicle based radio communication maybe the only feasible solution in some areas of the world. The TRIS project will investigate how future applications can comprise vehicle based missions and how the TRIS concept complies with contemporary command and control systems, such as Stridsledningssystem bataljon (SLB).

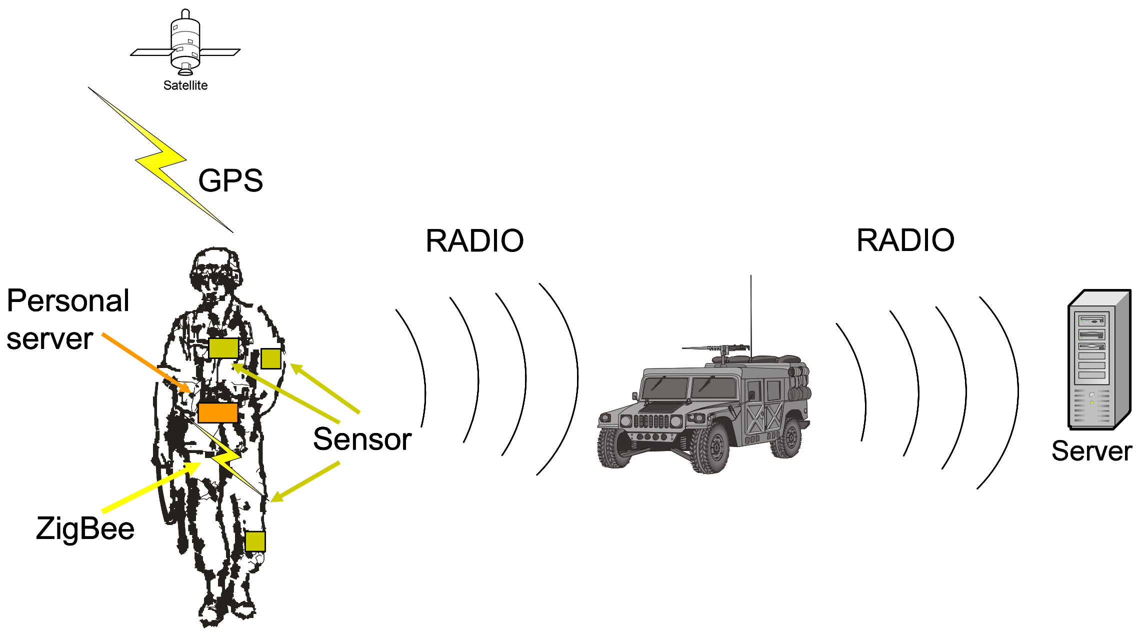

Figure 7.Radio based communication.

5.2 WIRP properties

Evaluation of the WIRP system will continue and comprise both technical aspects and the applicability of collected data. Acquired data will be assessed against other data collection facilities. The tests conducted are expected to generate the sample data necessary for tests of data fusion models.

List of abbreviations

GPRS	General Packet Radio Service
GPS	Global Positioning System
ISP	Internet Service provider
NTC	Negative Temperature Coefficient
UU	Uppsala University
WAN	Wide Area Network
WBAN	Wireless Body Area Network
WIRP	WIreless Research Prototype
WPAN	Wireless Personal Area Network

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