TACTICAL COMMAND SYSTEM IN FUTURE BATTLEFIELD

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Kirjoittaja on DI ja toimii tutkijana Maanpuolustuskorkeakoulun Sotatekniikan laitoksella.

TIIVISTELMÄ

Sodankäynti on jatkuvassa muutoksessa. Seitsemänkymmentä vuotta sitten taistelut käytiin metsämaastossa yksinkertaisin kommunikaatiovälinein. 1990-luvulla tiedonkäsittely muuttui rajusti tietokoneistumisen myötä. Kun maailma muuttuu, niin muuttuvat armeijatkin. Nyt, kaksikymmentä vuotta myöhemmin, armeijat kohtaavat jälleen uuden haasteen; tietokoneet ilmestyvät taistelijatasolle ja sota alkaa muistuttaa tietokonepeliä. Kuten kaikkina muutoksen aikoina, ratkaistavia haasteita on monia, mutta kun informaatioteknologia levittäytyy taistelukentälle, myös mahdollisuuksia on loputtomasti.

Tämä tutkimus pohjautuu kirjoittajan diplomi-insinöörin lopputyöhön [2], joka käsittelee johtamisjärjestelmän problematiikkaa taistelijatasolta aina pataljoonan komentajalle asti. Suuri osa työstä on demonstraatioympäristö, jossa tärkeimmät toiminnallisuudet toteutettiin. Perusratkaisuna käytettiin mobiilia ad hoc -verkkoa (MANET) jonka luoman verkon päälle suunniteltiin ohjelma joka välittää, luo ja sieventää tilannetietoa. Verkon tärkeimpiä ominaisuuksia ovat tukiasemattomuus ja uudelleenkonfiguroitavuus. Toisin sanoen verkko voidaan luoda laitteiden välille ilman olemassa olevaa infrastruktuuria ja verkko seuraa alati muuttuvaa tilannetta. Johtamissovellus tarjoaa käyttäjille hierarkkisen aseman mukaisen näkymän ja johtamisominaisuudet. Laitteen tarjoama käyttöliittymä seuraa ja muokkautuu käyttäjän tarpeisiin johtajan päätösten mukaisesti. Pääpaino on lähes reaaliaikaisen tilannekuvan ja karttapohjan välittämisellä, jonka kautta päätöksenteko ja tehtävän suorittamisen seuranta helpottuu, samalla käyttäjän tarvitsema perspektiivi huomioiden. Tämänkaltaisessa järjestelmässä käyttäjälle tulevat tehtävänaikaiset toimenpiteet on pyrittävä karsimaan minimiin ja sitä kautta automaation rooli on tärkeä. Testialustana toimi Archos 5 -multimediatabletti, josta löytyvät mm. WLAN, GPS, Bluetooth ja viiden tuuman kosketusnäyttö.

Tutkimus taistelijatasolle yltävästä elektronisesta johtamisjärjestelmästä on tällä vuosikymmenellä hyvin ajankohtainen. Kun elektroniikka kehittyy, pystytään luomaan kentällä toimivia järjestelmiä, joilla saadaan joukkojen suorituskykyä nostettua. Teorian tasolla järjestelmän osat ovat jo olemassa, mutta käytännön toteutukseen on vielä matkaa. Selkeitä tutkimuksen osa-alueita ovat ainakin käytettävän verkkoratkaisun tyyppi ja käyttöliittymän toteuttaminen hyvin stressaavaan taisteluympäristöön. Tämä tutkimus tarjoaa vastaukseksi ad hoc -verkon sekä taistelijan hierarkkiseen asemaan perustuvan käyttöliittymän. Koulutus on erittäin tärkeässä osassa taistelukentän tietoteknisen järjestelmän käytössä ja ylläpidossa. Koska laitteiden ja ohjelmistojen vanhenemissykli eroaa perinteisen sotamateriaalin elinkaaresta myös koulutukseen ja pysyvyyteen on syytä kiinnittää huomiota. Yksi vastaus tähän haasteeseen on hyvin selkeä ohjelmiston ja alustan erottaminen toisistaan ja sitä kautta käyttöliittymän sitominen aina tiettyyn koulutettuun ryhmään.

BACKGROUND

Waging war is in constant change. Seventy years ago the battles in the Finnish front were mainly fought in forested area with the communication devices familiar to that era. In the 1990's the way of handling the information started to change rapidly. As the world changes so do the armies and the computers entered to the battlefield. Now, twenty years later, the military is facing a new challenge again; electronic devices are being taken to the warrior level and the theater of war is starting to remind us of a computer game. As in all times of change there are many challenges to be solved but when transferring IT solutions to the battlefield, the amount of possibilities is indefinite.

This study is based on the writer's Master's Thesis [2], which discusses the challenges in creating a command system from the frontline warrior to the battalion commander's level. A large part of the work is a demonstration environment where the idea is taken into test. The test platform is an Archos 5 PDA device with WLAN, GPS, Bluetooth and a 5" touch screen display.

The future battlefield will be highly dependent on information transfer and creation. The reconnaissance information as well as real time information of the location of the troops will be an essential part of this information. These forms of information are familiar to the older systems but now the focus is in transferring from the higher levels to the warrior level. In this system the warrior and his/her equipment operates as a part of the network and actively routing the information as well as creating it. The warrior can be seen as an intelligent sensor node. This does not necessarily mean that the warrior has to use the devices. As in traditional static sensor network the carrier (tree, wall, etc.) does not know that a sensor is attached. At the same time the presence of the network and devices provides a large set of opportunities for the user. The network can be used as a communication gateway, sharing COP (Common Operational Picture) and to store and follow the mission.

To meet these expectations, many militaries have performed studies to find a reliable solution for the information network. One solution for this challenge can be found from MANETs (Mobile Ad Hoc-Network). MANETs have the capability to create and maintain a wireless network under varying situations and even by COTS (Commercial-Off-The-Shelf) ideology with military point of view included. Mobile ad hoc networks could create a solid base for C^4I^2SR (Communication, control, communications, computers, intelligence, information, surveillance and reconnaissance) systems considering network topology. The amount of information that is gathered with sensors is vast, and a reliable network is really needed as a base of the system. [1] [2] [3]

Even the best network solution is useless if the users are unable to use its advantages. In order to use the network, a device and a specific software is needed. The creation of the platform is rather straightforward but the situation changes when the context is taken into account. In the rough environment of the battlefield a high tech device is expected to be durable enough and to be able to store the power needed for many days. The challenges of the GUI (Graphical User Interface) also need to be taken into consideration because it is the only window for a soldier who needs to have the trust and knowledge to use the system.

This study is divided into five main parts. First, the general construction of the tactical system is presented in a theoretical level. In the second part, the important features from the implementation are discussed and the user interface views are presented. The third part discusses the possible improvements to the current status possible by using a new tactical solution. After this, the possible solution for creating long lasting educational system for rapidly developing IT environment is evaluated. In the last part, the conclusions are presented.

THE BASICS OF THE DEMONSTRATION SYSTEM

The demonstration system was created so that the application and the network layers can be separated, replaced or reused. Figure 1 describes the relations. The network layer is physically created by the devices, but it is not visible to the users in any

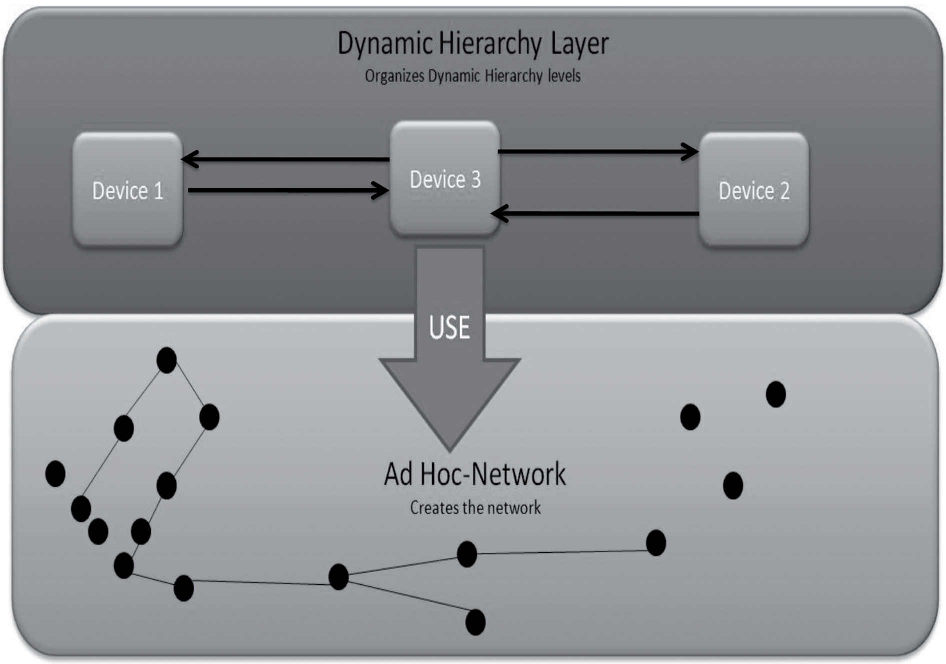

Figure 1 - *Relations of Network and Application*

way. The operating system of the devices uses the network to find a correct path to the node that it needs in order to communicate. The logic that can be used is stored to the application side as a whole and each device contains the same logic.

As the logic inside the application layer takes care of the structure of the entities, it also makes it possible to make decisions and to modify the information flows based on the structure. A good example of such information is the simplifying of information as presented in Figure 2. The figure represents a default case, where the nodes report their status to a higher rank node, which in turn simplifies the information into a simple message with only three integers. This message is then passed to the upper node and the stress in the network is rapidly lowered. In this example, the performance of the troops is being compared to an ideal case to discover a simple percentage, which can describe the shape of the troops.

The construction looks like a normal hierarchical system, but in reality, the system is organized by the network intelligence, which is created by analyzing the information delivered by each node. This construction is not to be confused with the organization of the physical network, because this construction is created by the information in the devices and it uses the mobile ad hoc network solution. [2][4]

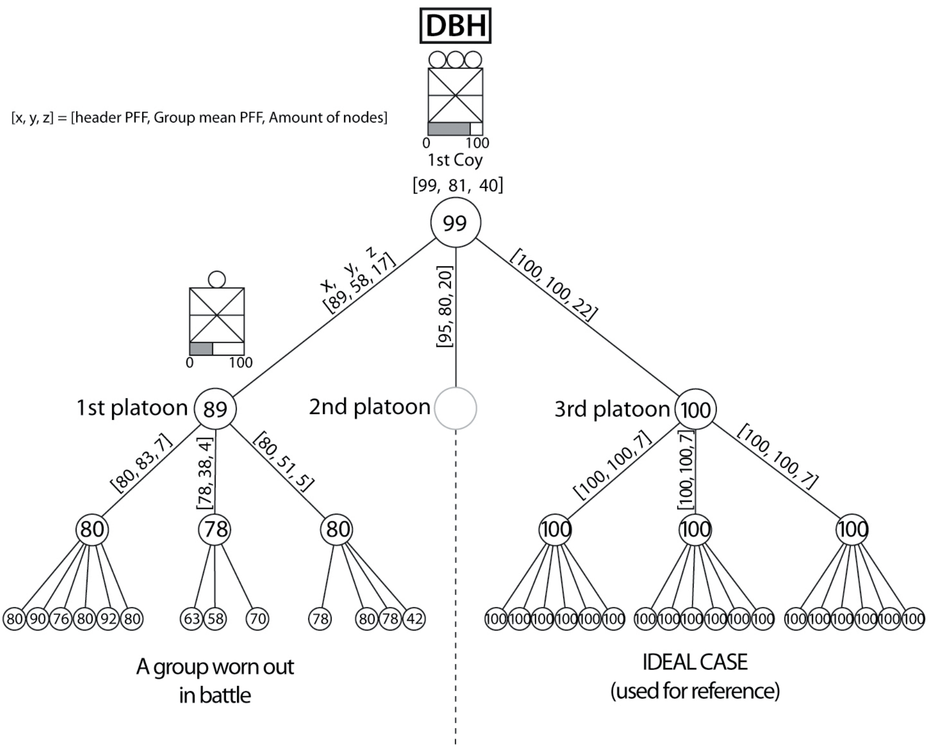

Figure 2 - *Simplifying the Status of the Troops*

Requirements for the network layer are heavy; no servers are allowed, no centralized logic in the network, no base stations or a centralized logic of which the network would be dependable. After evaluating the possibilities of such network, the only solution is the ad hoc network solution. It is a solution that offers means to create and maintain the network by devices alone, without any external components. The implementation of the used solution is based on the Mobileman project of the Aalto University. The layer is based on an ad hoc solution, which uses two main protocols for communicating; OLSR (Optimized Link State Routing Protocol) and AODV (Ad Hoc On-Demand Distance Vector Routing). The OLSR is a proactive protocol, which communicates with the nodes even when there is no specific traffic, whereas the AODV only operates upon connection request. These two components create a hybrid protocol that is capable to communicate efficiently to nodes nearby or to find a route through the network to a specific node. In Figure 3 the relations are presented. [5][6][7]

The communication to outer world is an important factor in a tactical system. As stated earlier, the ad hoc network is created only for creating communication gateways inside the system. For this purpose, an information transfer gateway is needed for external communication. In this study, it is a simple external server delivering NFFI (Nato Friendly Force Information) message from a web service. Any of

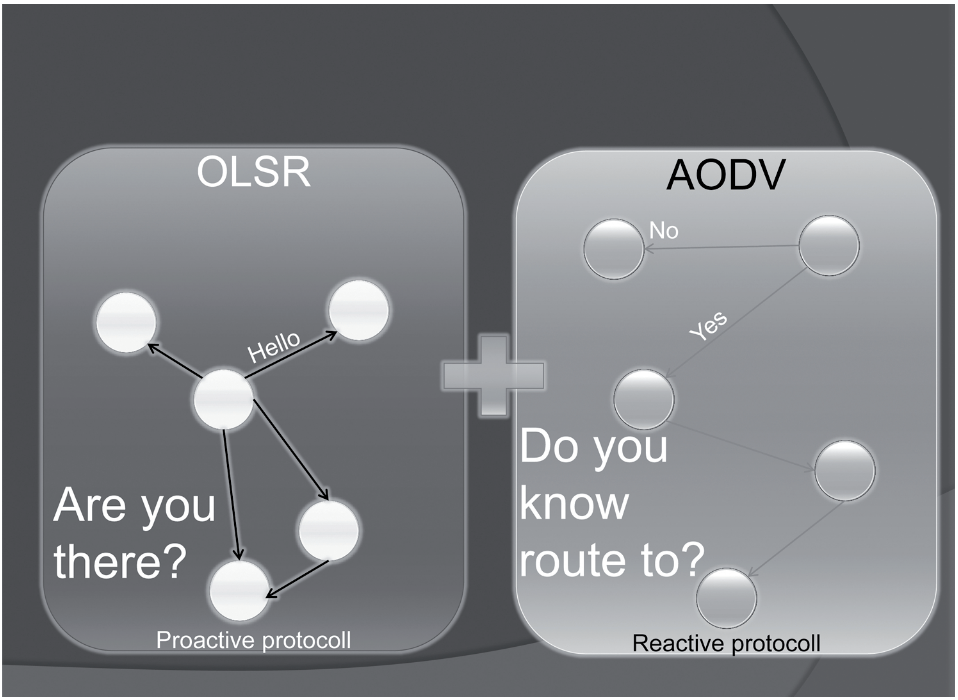

Figure 3 - *Network Protocols*

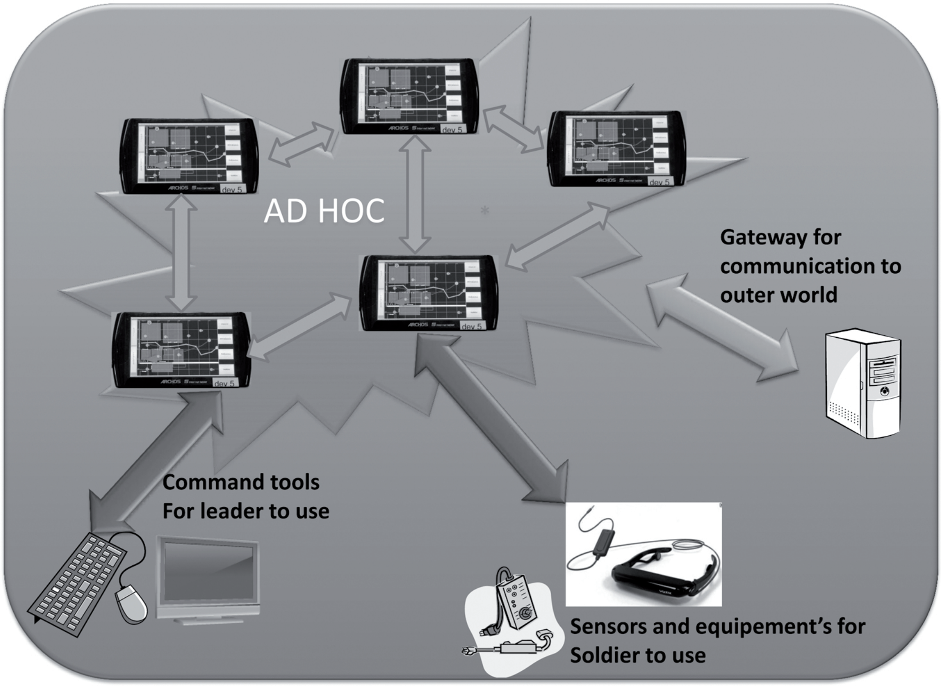

Figure 4 - *Entities*

the devices in the network including a suitable gateway can publish the information of the entire ad hoc network so, that the higher level is able to see the status. This feature was only partially implemented. In addition to external communication, an efficient way of adding more features to the device is also needed. This can be divided into two subclasses; soldier's equipment and commander's equipment. A soldier needs a good level of integration of the system to other entities such as weapon and clothing. This will require a standardized interface to support future use and common guidelines. A commander needs a set of tools to see the bigger picture and to use the information. These tools are, for example, a keyboard and a bigger display. The entities in the system are presented in Figure 4. [2]

INSIGHT OF THE DEMONSTRATION SYSTEM

A big part of the research was the demonstration system implementing the core features. This chapter describes the main features implemented.

Some important features:

- Dynamic view change
- Dynamic rank change

- Ad hoc network
- Automatic update of COP (Common Operational Picture) and sharing
- Possibility to create and update map dynamically to all devices
- Possibility to create and update mission and mission critical information dynamically to all devices
- Interface for self-locating network

Figure 5 - *Troopers Display* (Kuvakaappaus ruudulta)

The dynamic view and rank change are features that are tied to each other. A superior node has the possibility to promote or denote the nodes under his command by using the system. By this way the view in the user's device also updates according to the status in the hierarchical construction. The troopers display, for example, is blank, whereas the Company Commander is able to see the units, map and COP information as well as the nearest nodes and their ranks. In Figure 5 the lowest level of information is presented; only the trigger and location buttons are active.

In Figure 6 a higher rank view is presented. The system delivers a COP by drawing color inside rooms when the information is available and by illustrating the usage of weapons with a blue triangle directed to the direction of engagement. The information presented is automatically created in the device and shared across the

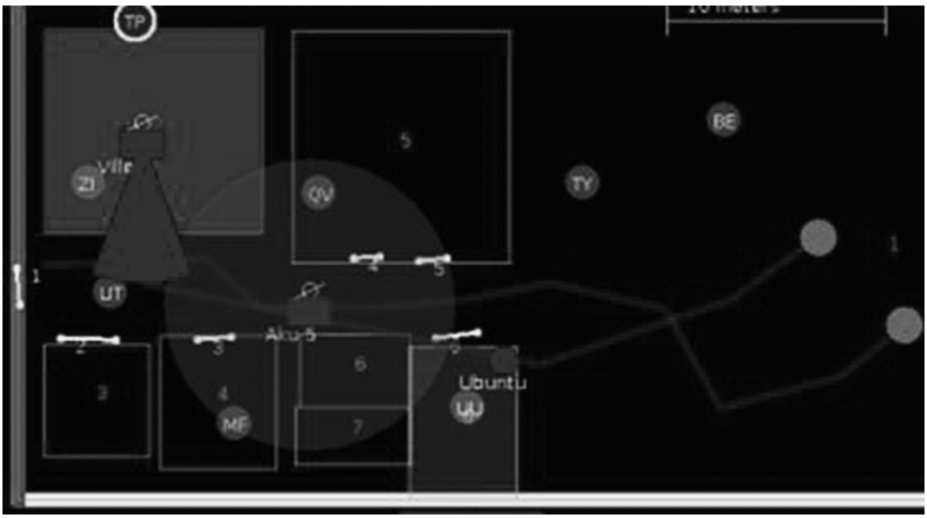

Figure 6 - *Company Commander's Display* (Kuvakaappaus ruudulta)

network. With the system it is possible to create and update the base map during action. When new information appears, it can be drawn to the map in any device and shared instantly to all devices in range. The mission updates and the overlay point updates follow the same pattern. As can be seen from the picture, one point is different; it is the intrusion point, which is mission critical information. The system creates this overlay point automatically by selecting the first created point as an intrusion point.

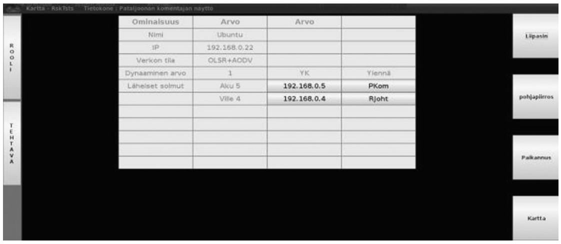

Figure 7 - *Company Commander's Menu View* (Kuvakaappaus ruudulta)

The Figure 7 presents the view of the company commander's inside menu. This view presents the information of the nearby nodes and their ranks. From this view, the user is able to change the rank if needed and to see the call sings of the nodes.

The systems implements five different levels: warrior, squadron leader, platoon leader, company commander and battalion commander. Each of these ranks has different scale in the map and different possibilities for leading the troops or in following the COP. The creation of mission or blueprint is only possible in the two highest ranks. The ranks are bound to military ranks for demonstration purposes but the real meaning behind them is the customization of user interface that can be adapted to many different situations, not tied to ranks.

The location services will play a major part in future's warfare. That is why an interface and logic was created for the network to self-locate the node in the map. The device used in the demonstration has the GPS (Global Positioning System) chip installed, but from the research point of view it is reasonable to try to find a location solution that does not rely on any external components, such as satellites, that are not under direct control of the Finnish Defense Forces. The key idea in locating is to measure the travel times of signals from one device to another and the power level of the specific nodes. The distance to the measured node can be calculated based on this information. The node offering location information is static and knows its own location. Based on this information, it is possible to draw a circle that contains the device requesting the location. Once there are enough sources of location, it is possible to calculate the location. When the network is on the move, the system automatically starts to share the location when a node is standing still. In the beginning, the original location information is needed, which can be accomplished for example by placing a sensor node to the outer walls of a building just to deliver their position. The idea is presented in the Figure 8.

The location using WLAN (Wireless Local Area Network) is studied quite comprehensively but not taken into real use. The approach tends to be focused on solid stations, which of course is the normal situation in a managed mode WLAN. [8][9]

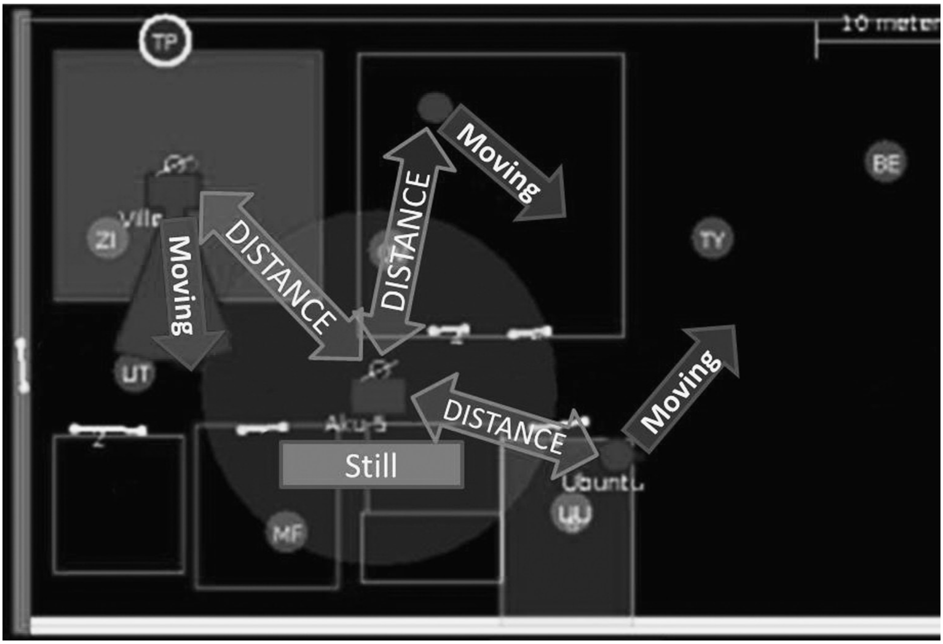

Figure 8 - *Location* (Korjailtu kuvakaappaus ruudulta)

[10] The idea of locating in MANET (Mobile Ad Hoc NETwork) is a reasonably new idea and could be adapted to the use of military networks. During this research, the location was investigated but it was forced to be left to the background.

POSSIBLE IMPROVEMENTS TO CURRENT SITUATION

Current tactical system has developed through decades, so it has a solid base of knowledge. By no means it is reasonable to start changing the existing system, but to study the phenomena in the battlefield and to try to improve results and effectiveness of own troops. The focus in information technology system is in SA (Situational Awareness) side, where the COP and base map can be easily presented. Supporting decision making and fast response is a key area in the research.

Automation is an important feature in all computer based systems. Computer is a very fast tool in simple calculations and in sharing information. After interviews made during the research, it was obvious that majority of information is shared through VHF using normal speech. A variety of different information can be changed into digital form, processed with the device, and sent through the network for others to use. This technique would rapidly scale down audio traffic and also improve the understanding of the information because the presentation is tied to an existing map base.

Examples of information that can be automatically processed:

- Location information – shared automatically
- Mission status – are the troops on schedule?
- SA information – weapon fired, discovered explosives, etc.
- Calculating performance status
- Mission status

The most visible improvement to the troops is the map shown in the display. During the interviews it came up that different presentations of the map are needed. For example, satellite photography, terrain analysis, and normal map could be needed. Fundamental difference to the current system is the ability to present the structure of the troops really close to real time. The enemy information is presented based on observations of the troops or automatically shared when a weapon is used.

When in contact with the enemy, the system is able to rapidly show where the fire is coming from. As the first friendly shot is fired, the leader is able to see the direction and the volume of fire. This will show the direction of the hostile troops. Also, when in contact, there is no need to contact the upper hierarchy level anymore, since the system will take care of delivering this information. In Table 1 the possible improvements are presented. [2]

THE LIFE CYCLE AND EDUCATION OF AN INFORMATION TECHNOLOGY SYSTEM

An essential part of a software product is the estimations about the use and life cycle of the software. The importance of maintainability is essential especially in a military environment, where the product is expected to last for a long time period, because even the acquisition process can take many years. The civilian IT market does not make any effort in prolonging the life time of the products; instead the idea is to make new products constantly and to make the consumer buy the refreshed product. As the technology evolves faster than the expected software life time, a solution is needed. As an example we can estimate that the average life cycle of the used hardware is from four to six years. At the same time the software solution can be expected to last for fifteen to twenty five years (in military environment), if it is made in such a way that it is reconfigurable and also meets the needs of the users. The use in militaries varies notably from the use of a regular consumer. There is no need for new interesting features, brand or concept but for a reliable, tested and proven solution for the use in battle. This image is somewhat in conflict with the arisen idea of using COTS (Commercial Off The Shelf) technology since it evolves on the terms of consumer electronics.

From educational point of view, it would be extremely usable to statically define the shape and form of the user interface. As the troops are trained to use certain

Possible improvements			
Phenomenon	**Current status**	**Ideal situation**	**Means to accomplish the improvement**
Evaluating the shape of the troops (structure, mental, physical)	Based on empirical evaluation. More difficult in higher levels.	Leader has the information which is accurate and based on real time situation.	Comparing the information to the ideal reference model and presenting the information in a simple percentage number bound to base map.
Ability to realize the situation when ambushed	It takes approximately one minute from the leader to form an estimate of the situation and to act.	The Situational Awareness is gained under ten seconds from the shots fired.	Providing detailed information of the location of troops and activity real time in the map of the device.
Simplifying process of the information	Leader will evaluate what is important and provide information to the upper level using a radio.	All the trivial information (location, condition, tasks) are processed automatically. Leader node does not to take part in the process.	The devices will perform the simplification and deliver the information to the next level automatically.
Leader using VHF radio	Leader actively needs to contact own troops and superior command.	All the trivial information (location, condition, tasks) are processed automatically.	Automatic messaging inside the system.
Decision process	Leader will make notes of the situation, use map and intelligence and then form a decision.	Important information is automatically combined to the display for the help of the leader.	Creating a view to the device that supports decision making in different situations.
Dynamic Hierarchy	Leading position changes according to superior's decisions and communication.	A leader is able to change the leading structure of subordinate troops quickly and efficiently.	Offering means to change the hierarchical level of the node for a leader. User has different views and functions according to the status.

Table 1 - *Realized Improvements*

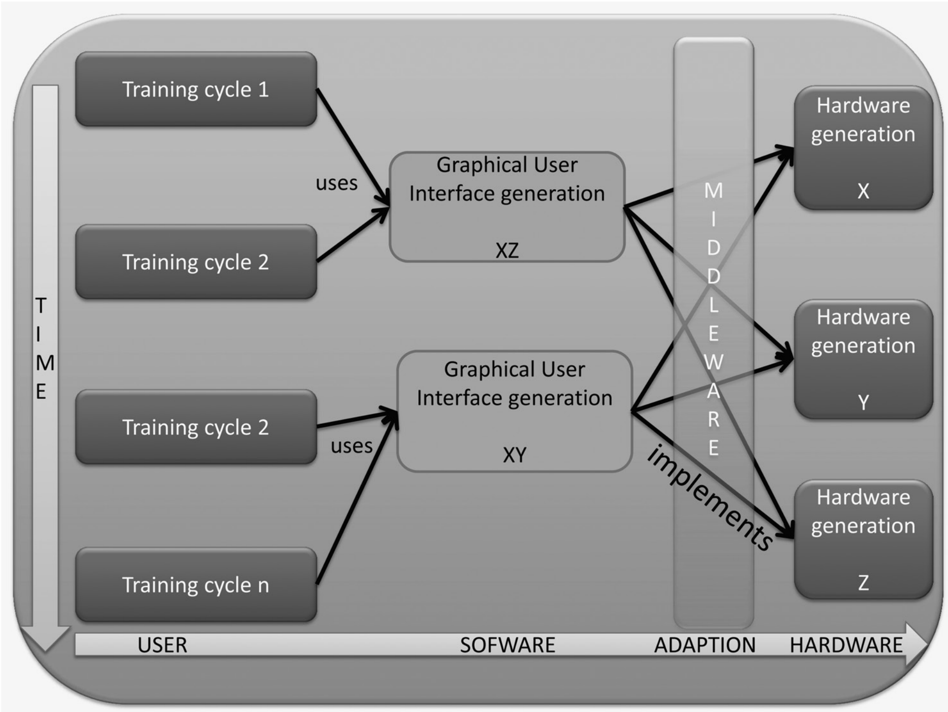

Figure 9 - *SW Life Cycle*

equipment and then sent to reserve when the military service ends, it is expected that the troop will maintain a certain level of performance for a number of years. The soldiers expect that the system's graphical user interface stays the same in a conflict or in a refresher training. The functionality or network solutions are not important information for a user if they work as expected. When considering the cycle of refresher trainings or the event of a possible conflict, it is likely that the hardware used in original training is deprecated. In this case, it is essential to get the troops operating effectively as fast as possible. Usually there is not enough time for extensive retraining with devices since the focus is in tactics, not in the devices. Figure 9 describes a possible solution for deploying long term solutions from the educational point of view.

As the trainees are trained and bound to a certain implementation graphical user interface generation, the hardware level implementation change as the technology evolves. When considering refresher training, we see that the graphical user interface implementation for Training cycle 1 is supported by Hardware generation 2. This makes it possible that a set of trainees is able to use the original look and feel that they are trained to, even after many years. The ideology is the same as in modern war equipment; every course is tied to a certain set of equipment and they will practice with the same set in the future, even when the material evolves with the

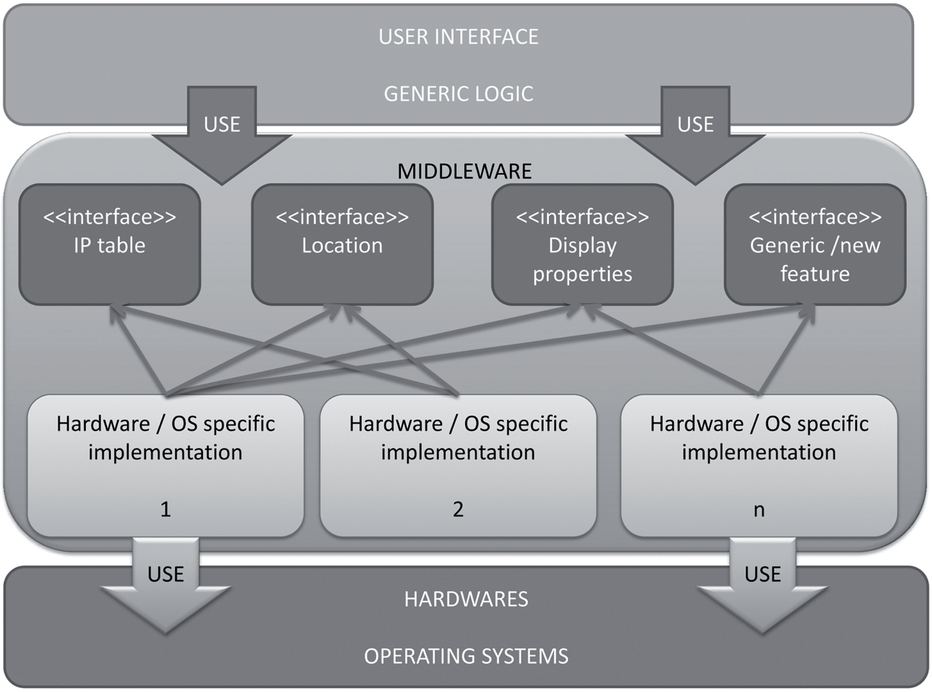

Figure 10 - *Minimizing Platform Dependency*

currently trained troops. [2]

Separating hardware from implementation is quite difficult in mobile environment. In finding a long lasting solution for military use, it is essential to create a framework that supports the long lasting software ideology and enables reuse as well as changeability. In Figure 10 one possible solution for weakening the dependency is presented.

The first and most important phase, as in any software project, is defining the needs and deriving the requirements. Based on this information, it is possible to recognize the individual types of information that are needed by the software. When the set is recognized, units can be derived to specific interfaces which will support the software life cycle. The implementation for these interfaces can then be offered by operating system specific entities. During next user interface designs it is possible to create new features by adding a new interface and using it from the application. This does not break the older implementations so this would be suitable for iterative development. After the interfaces are formed, the information is in the right form – regardless what specific implementation is in use. The information that is derived by the middleware layer is kept in the simplest form and no logic is maintained here. Examples of such information are getting the device IP address, fetching the route table of the device and discovering the devices screen properties for the user interface. Typically, the way of getting this sort of information is to run operating system specific scripts and parsing the information for upper levels to use. The upper level (User Interface and Logic) takes care of the user actions and displaying information, as well as all the logic in the system. [2] In addition, there is a possibility of using HAL (Hardware Abstraction Layer) in raising the abstraction level from hardware side and to improve the possibilities in pre-development. [11]

This offers possibilities to change to a different platform. The middleware can also be implemented with Java so that the operating system specific scripts are stored in Java classes. In the demonstration environment the ad hoc layer was implemented in C so there was a need to get to the native queries for finding IP route tables. It is likely that the networking protocols cannot be implemented in a high level language such as Java because of efficiency issues and restrictions of virtual runtime engines. At the same time, the possibility of using for example C++ or C for implementing the whole system would make it more difficult to change from O/S or platform to another solution. [2]

As a conclusion for this chapter; even though the implementation appears to be really loosely coupled to the operating system, there still are requirements that the software contains towards the used hardware/operating system combination. If an ad hoc network solution is being used, it is very likely that the need for running native operating system queries persists. This situation requires either running a specific native scripts as described or adding the needed functions to Java native library for use. The last option is reasonable if there will be multiple platforms and combinations. This probably requires a bit more work since the implementation must take into account of all the same scenarios and to build these functions inside the language itself.

CONCLUSIONS

As an evaluation of the work, the overall impression is that research in this area is valid and interesting. It is not common to see demonstration systems that are focused in operating without base stations. There are many studies involved in this area but not many are focused on the big picture with the really multidimensional field, but are more specific in nature.

Rather than just focusing on the technical side of the development, it is important to realize the educational needs of a large organization that traditionally plans the needs for future decades instead of just for few years ahead. This is not the normal case for rapidly developing software and hardware products. At the same time, the commercial products, that have created the idea of military use, are originally intended for stress free environment which needs to be taken into account when developing systems.

It is clear that as the operations are more widespread and beyond the infrastructure of friendly forces, new means to accomplish networking are needed if satellite services are not under direct control of the user. As the networking solution is developed, many needed functions, such as location, could be integrated to a network level solution. Automation will be a big part of the functionality. It simplifies the operation and minimizes the needed actions of the user as well as improves the situational awareness. The arrival of information technology will change some of the procedures in the battlefield, but the focus of the future systems will likely be in a form of support system that does not dictate the tactics alone.

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