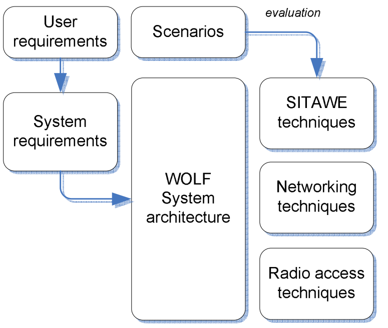
WOLF - Wireless rObust Link for urban Forces operations

The WOLF project, funded under the 2nd call for proposals of Joint Investment Program on Force Protection (JIP-FP), was carried out from early 2009 to early 2011. The project was run by a consortium of 13 partners from 8 countries, that bring together major key European players in the domain of soldier radios, networking and software define radio technology.

The project addressed the following priorities: tactical communication, information processing and situation awareness, and aimed at delivering the concept definition within a proposal of harmonised scheme for a new radio transmission system suitable for tactical operations in an urban environment. As such, the aim was also to develop a consensual vision that could drive further work on a future European standard.

The project was organized as follow: First, operational needs were gathered through end-user interviews and partner expertise in military communication. From this, a proposal for system architecture was made; system requirements were defined. Finally, techniques for situation awareness, networking and radio access were investigated, specified and evaluated through simulations and demonstrations, using relevant scenarios.



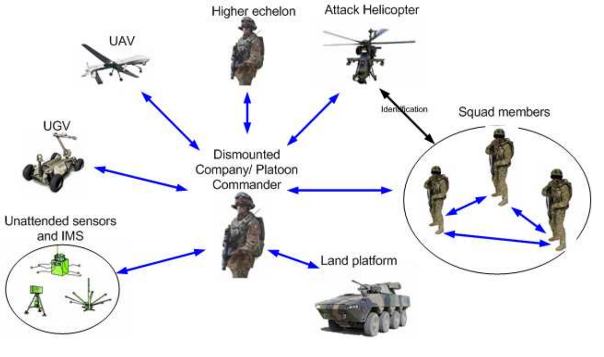
User requirements

Modern warfare trends towards

Demographic trends indicate that the further urbanisation of cities will continue and as a consequence the urban area is expected to be a major battlefield in the future military operations. Operations in an urban environment require intensive use of ISTAR capabilities, under severe time constraints. Urban operations bring specific challenges for the soldier communication system, among these are:

- Modern operations require a variety of services in addition to voice: video feed, data for situation awareness, C2 and identification. Some of these services require high-throughputs when spectrum and radiated power are limited
- Most of the communication are short-range and out-of line of sight, with a need for relaying (ad-hoc networking).
- Radio must be robust against harsh electromagnetic environment (interferences, jamming, multipath propagation)
- GNSS (such as GPS, Galileo) used for positioning and network synchronisation is likely to be jammed, and is often unavailable (indoors operations).

More generally, a reliable, secure and robust communication solution must be provided down to the lowest echelon in order to increase the soldier survivability and mission success.

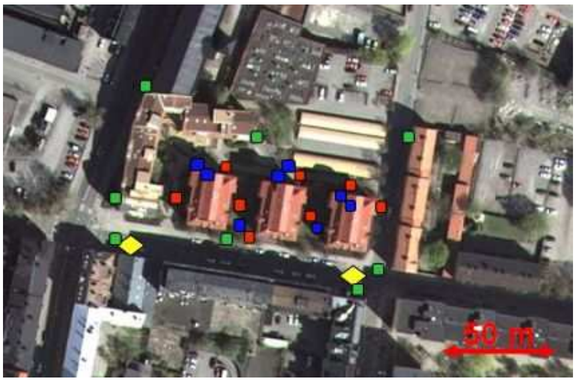


The first action for the project was to clarify the operational requirements, developing a scenario including three tactical vignettes and interviewing end-users from all participating countries.

The WOLF scenario is about an armed fraction (100 to 150) causing tensions in a middle sized city, with possible terrorist mode of action. An International Force is commissioned to disarm the armed fraction and provide humanitarian aid to the inhabitants. The size of the International Force is an Infantry battalion of three companies and support units including a reconnaissance platoon, a logistics company, a UAV company and a medical company, in total 1000 troops.

From the scenario, three tactical vignettes were developed to visualize the operational requirements. The first vignette *attack and clear a building* is the one that most influenced the operational requirements. This vignette shows an operation having many troops in a limited area, and illustrates the need for a single network on company level.

Capabilities were confirmed, refined or even extracted from the scenario Mission Threads. Operational impact of each capability requirement on mission progression has been analyzed, and ranked (low, medium or high).



Following the NATO Architecture Framework (NAF), operational and capability views were built: activity node tree, NOV-2 (NATO Operational View) for connectivity description, NOV-5 for activity model, NOV-3 for information exchange. Based on the Operational View OV-3, information exchanged between nodes has been analyzed in terms of throughput and delay constraints. It appears that most of the transmitted traffic is provided by nodes with devices for collecting images and video with high resolution, such as land platforms, unattended sensors, UGV and UAV. The collected files are mostly sent to squad commanders and to platoon commanders to be analyzed. Correspondingly, squad commander is a node with a high transmitting activity.

Node	Received data [kb/s]
Company Commander	2896.7
Platoon Commander	2393.
Squad Commander	732.0
Land Platform	663.8
Attack Helicopters (limited scope)	1.14
Team Member	258.6

System architecture

The WOLF system definition, carried out in the 2nd semester of the project, aimed at

- Defining the WOLF system, as a set of interconnected nodes forming a communication network; a set of example applications were described in order to explore the services that the WOLF system provides, from tactical image exchange to situation awareness.
- Considering this system paradigm, deriving the system requirements from the operational requirements defined earlier
- Proposing a system architecture for the communication system, derived from the CALM (Communications access for land mobiles) and 802.11E models. Two paradigms are especially investigated. First, emphasis is put on the Quality of Service, which should be monitored at several system levels using cross-layering mechanisms. Second, security aspects are analysed based on a detailed threat analysis. A high level overview of security measures is provided, categorizing the mechanisms roughly in a few high level groups. All mechanisms are shown in an overview in order to clarify the mechanisms per layer.
- Allocating the technical requirements to the system sub-modules in order to drive the specifications performed in the technical Work Packages dedicated to the networking module, radio module and situation awareness module.

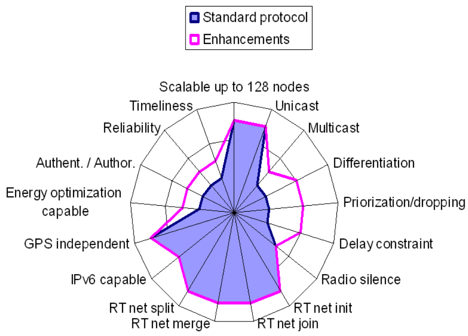
Waveform specifications

The obtained technical requirements followed by analysis of existing protocols and techniques and novel solutions to fill the technical gaps yield to the specification of the waveform, from the Networking layer down to the Medium Access Control and the Physical layers.

Networking

The main challenge of the networking definition was the choice of topology and routing mechanisms adapted to urban communication for end-to-end connectivity.

A state of the art analysis was carried out by taking into account the operational and system requirements and assessing these requirements using a TRL-like (Technical Readiness Level) evaluation method. This led to the selection of the OLSR protocol as the root protocol for the specification of the WOLF communication system NET layer.

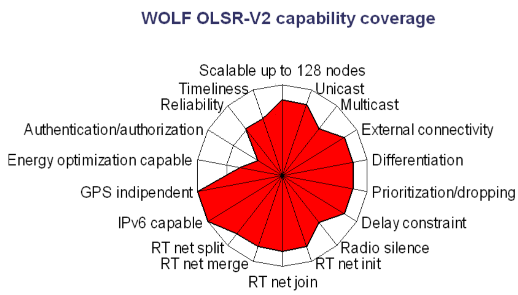


Then, the second phase of the study defined specific features and enhancements to the actual OLSR protocol to cope with the specific WOLF requirements such as survivability, radio silence, multicasting and QoS handling.

The design of mechanisms to provide QoS support for delivery of real-time audio, video and data in WOLF systems presents several technical issues. The QoS framework should be flexible enough to support several traffics with limited resources in a highly dynamic environment. The study focused on specifying the QoS model, the QoS resource reservation signalling and the QoS routing metrics to support QoS in WOLF communication systems.

Finally, a design for WOLF OLSR-V2 was proposed and evaluated. An overview of the key aspects of OLSRv2 was given with a specific focus on the protocol aspects that are extended in the WOLF routing protocol. Differences between WOLF-OLSRv2 and OLSRv2 in order to meet the WOLF system requirements are:

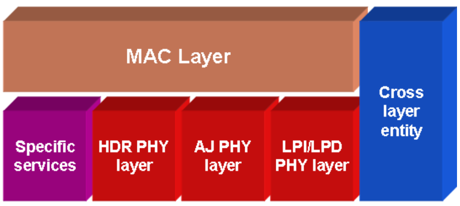
- gathering of the 1-hop and 2-hop neighbourhoods information
- information bases required to calculate routes
- information contained in control messages
- procedure to achieve flooding optimization.



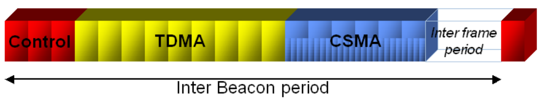
Networking demonstrations were performed at the end of the specifications, on October 2010 in Sagem DS, Eragny, France. This demonstration showed the deployment of a squad of soldiers around a building with an operational objective of doing observation. Ad hoc services were implemented over existing platforms to demonstrate mobility management, routing performance and interoperability between different Radio Systems (Joint Combined Forces).

MAC layer

The MAC layer objectives is to manage transmission and reception resources in order to reduce interferences and ensure waveform interoperability, but also to provide the networking layer with a topology and the physical layer with parameters (coding, modulation) according to link quality and data traffic requirements. From the requirements, MAC layer is responsible for the interoperability with Radio-Based Combat Identification (RBCI) waveform, and interoperability between different physical modes (low data rate, high data rate) that could co-exist in the operation zone.



For physical layer interoperability, a MAC frame structure and scheduling modes (centralized and distributed) are proposed and evaluated through simulations, based on the *attack and clear a building* vignette. As a conclusion, mixed solution shall be established, exploiting distributed mode strength in high mobility cases and jumping to centralized mode for more stable situation.

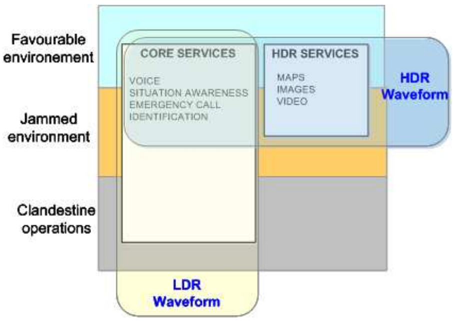


Physical layer

The main concern that drove the physical layer studies was the definition of physical access that enables robust communication (propagation, robustness to jamming and interception) in urban terrain but also supports the requested services, from critical low bit-rate services such as emergency call up to desirable high bandwidth services such as video transmission.

The first part of the physical layer studies was a frequency analysis. Two frequency bands are identified for the future communication system: UHF [225-400] MHz for its good propagation properties, [1.3-1.7] GHz for short-range/ high data rate modes, and [2.0-2.3] GHz as a back-up possibility. A propagation study in urban area was carried out, based on existing analytical models and data from radio sounding campaigns. These models are later used in the simulations of the physical layer waveforms.

Then, specification of the physical layer was carried out. The technical requirements highlight the need for 3 different Low Data Rate (LDR) modes and 1 High Data Rate (HDR) mode under the same MAC layer.



For the Low Data Rate waveform, specifications for the AJ (anti-jamming) mode and the LPI/LPD mode (Low probability of Interception/ Detection) are proposed, with a gross data rate ranging from 30 ksymbols/s up to 250 ksymbols/s. Different FEC (Forward Error Correction) schemes help reaching different throughputs and robustness. The simulations results show the expected coverage in various propagation environments and sensitivity to jammers for the different modes.

The High Data Rate waveform is intended to support high bandwidth services for today (UAV, UGV, sensors, transmission of maps) and for the future (combat camera). It is scalable in bandwidth (1.25 MHz and 5 MHz channel spacing), in dedicated channels in the 1.3 – 1.7 GHz band with fixed frequency (FF) or frequency hopping (FH) capabilities, or in the military UHF band (225 – 400 MHz) with FF only capabilities.

From this, the most promising candidate techniques are identified, specified and simulated. Range requirements from the CONOPS (700m outdoors) are fulfilled with all the waveforms. The two most promising candidate techniques are:

- Multi-carrier signals (OFDM) due to their good multipath channel properties, simplicity (easy equalization using the cyclic prefix) appears as a promising technique in future implementations. This scheme proposes highest throughputs (typical = 2.3 Mbits/sec), but sets higher constraints to the radio device and has a lower power efficiency, leading to 160 m of expected indoor range. A technological analysis regarding radio constraints would be recommended to determine if the current limitations have been solved in order to take advantage of the multiple benefits that could be reached using OFDM.
- Continuous Phase modulations (CPM), with time domain feedback equalization that exhibits higher power efficiency and lower radio chain complexity. It offers higher ranges (182m indoors), at the cost of a lower spectral efficiency compared to OFDM. Regarding the range-oriented requirements, CPM appears today as the best recommendation.

Physical layer demonstration was performed in October 2010 in Thales Communication, Colombes, France. It was successfully demonstrated that specified waveforms are capable for video streaming in real indoor environments since the used link was from the 6th floor down to the ground level of a modern concrete building. Improvements offered by multiple antenna receiver techniques were also demonstrated.

Keeping in mind that the proposed waveform and solutions are intended to be implemented on future platforms, a study of SDR implementation feasibility has been performed. This work shows the ability of existing SDR platforms to support the specified waveform. Based on complexity analysis of the waveform components, recommendations for future platforms are provided.

Situation awareness

The situation awareness studies address specific technical areas that contribute to the awareness increase: sensors fusion, soldier positioning and identification. In addition, models and mechanisms for build, sharing, and present the Common Relevant Operational Picture (CROP) in real time have been investigated

The first issue was about finding a way to efficiently make the data fusion, considering constrained network, in an environment were the number of disseminated sensors is constantly growing up. Based on the use cases derived from the WOLF scenario, sensor traffic analysis is performed and leads to the conclusion that intelligent sensor collaboration and management could be the key to efficiently build, improve and disseminate situation awareness information in bandwidth-limited tactical networks. Means to achieve accurate and reliable soldier positioning was the second major objective. The main technical challenge is to obtain a high level of accuracy and reliability in tough environments without using preinstalled support systems, with seamless outdoor-to-indoor functionality. Cooperative positioning based on foot-mounted inertial sensors and UWB RF ranging is identified as the best-promising approach, as confirmed with experiments performed during the project. A concept including sensors, algorithms and sensor fusion is proposed. The corresponding sensors fusion, based on Kalman filtering of different information sources is proposed.

The third study area focused on the feasibility of integration of the Radio Based Combat Identification in the WOLF waveform, considering that identification service can dramatically increase survivability by decreasing the probability of fratricide fire. Requirements, as confirmed by simulations, are defined and shared with the MAC layer design.

Finally, a situation awareness architecture is proposed, based on Service Oriented Architecture (SOA) principles, which improves the dissemination of the tactical information. Data models which provide interoperability at different levels (tactical up to strategic with C2 systems) are proposed, taking into account both the information needs at different echelons, and the limits of the bandwidth and (computational, memory, battery life) of soldier equipment. The generation of the Shared Real Time Situation Awareness Picture in the tactical environment benefits from the fusion of primary importance consists in the correlation of the tactical Common Relevant Operational Picture ("Top Down") with the real time sensor information generated by the sensors at the soldier. ("Bottom Up"). Optimizations of data dissemination, taking benefit from the use of temporal and spatial meta-information, apart from COI's, were proposed. Situation awareness studies ended with a demonstration, held in AmperLab, in Getafe, Spain, in September 2010, where some of the studied concepts were implemented and used in a relevant urban scenario. It was thus shown that it is feasible to implement such proposals in real equipment and within an urban environment.

Conclusion

One major goal of the WOLF project was to propose and evaluate solutions, which allow addressing the technical challenges for tactical communications in urban operations.

Based on a detailed operational requirement analysis and a proposal for system decomposition, high level specifications have been proposed for the networking, the radio access layers and the situation awareness service. The most promising techniques have been identified and sometimes combined solutions have been proposed in order to address the challenges brought by the urban environment. Those recommendations were confirmed or refined through simulations and demonstrations, using relevant scenarios and technical parameters (traffic, mobility, models for propagation channel).

Of course, not all of the required aspects could be addressed in the framework of this study; at the system level, security was revealed as a critical issue that could not be handled separately from the waveform specifications, and that can impact the system performances at many levels. Also at the technical studies level, complementary investigations will be required in order to reach the proper level of maturity for a future standardization proposal.