NOAH AAL Project Documentation

Deliverable 5.5

Mid-term report

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Summary

Introduction

This report describes status and summarizes major achievements of the NOAH project during the first half of its duration.

With respect to the original proposal, the work plan has changed, based on recognitions carried out in initial phases of the project. Changes, however, are fully compliant with overall project goals, as declared in the proposal, and have been implemented in order to better suit the original purpose. In the proposal, it was stated that the NOAH proposal should have envisaged *a "light-technology" approach, based on inexpensive and unobtrusive monitoring techniques, on familiar and accessible interaction tools and on cloud-based data processing*. Features we had to seek for include:

- ***Intervention cost** should be affordable, sustainable and justified by clear value proposition. Hence, marketability studies and deployment strategies will be at the core of the design flow. A tentative cost figure in the 1k-2k € per user (projected on small-scale production, depending on actual service configuration upon specific needs, home characteristics, etc.) seems to be reasonable and, based on previous experience, within practical reach.*
- *Design efforts should be primarily aimed at **service deployment**, besides basic technology development. The NOAH proposal is based indeed on an almost complete layer of validated basic technologies, to be harmonized in an innovative service view and thoroughly tested through pilot studies. I.e., giving for granted proof-of-concept and feasibility studies, most technical design will be devoted to accessible and incisive interaction techniques, to devise and test simple and reliable installation and maintenance procedures, to develop automated behavioural analysis services, to deal with system ergonomics, accessibility and user acceptance. The "last mile" toward a practical and usable service will be therefore at the very center of a user-centric design process, involving users and stakeholders in the service specification phases as well as in extensive testing and iterative tuning.*

In summary, we expect the project to result in a complete, ready-to-use package, suitable for enabling families and homecare providers to easily install, manage and operate NOAH services out-of-the-box.

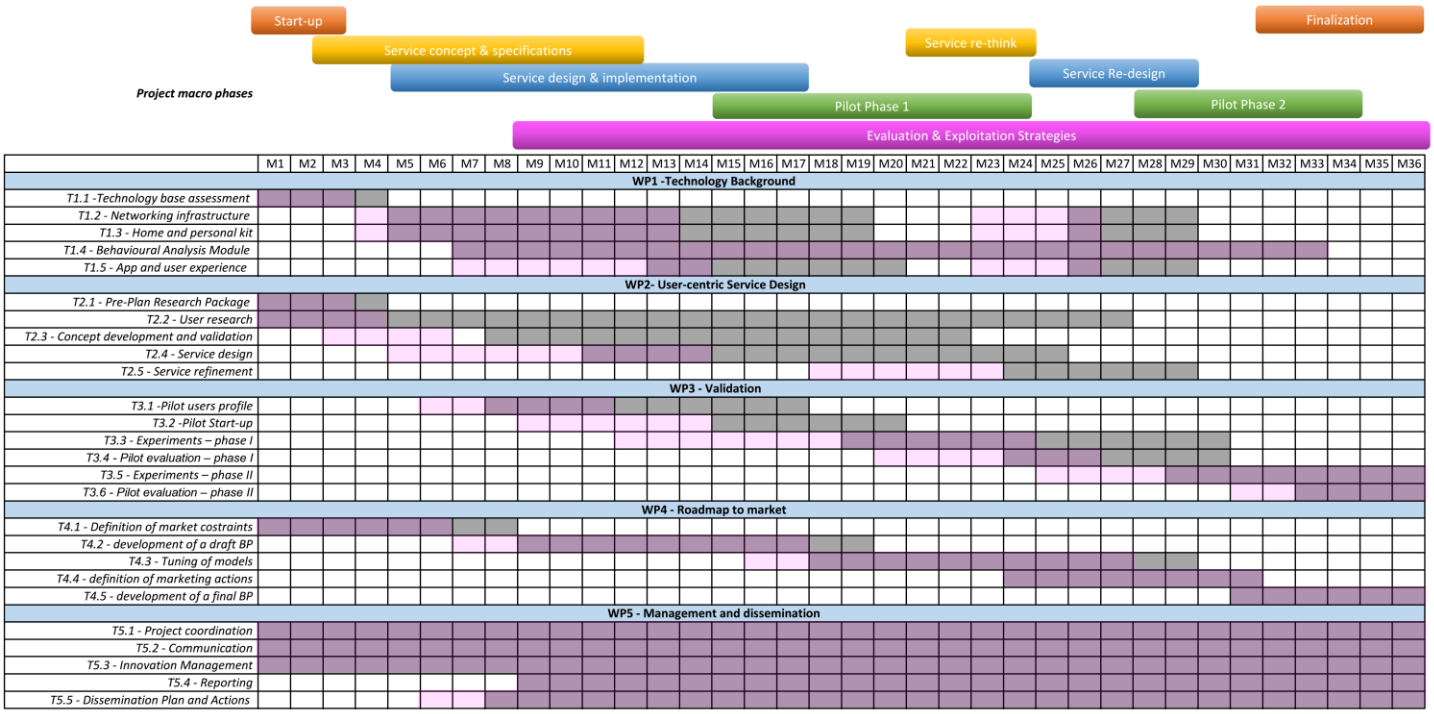
The overall technology vision was based on the deployment of a wireless sensor network, suitable for indirect monitoring of daily life activities, coupled to artificial intelligence tools aimed at discovering meaningful behavioral patterns, anomalies and trends. We did not start from scratch, since part of the technology approach was already been tested in previous projects (in the AAL-JP framework, most notably the HELICOPTER and ENSAFE project, involving some of NOAH partners). Based on such experiences, however, we realized that some more radical technical development was needed, in order to match costs and usability goals mentioned above. In particular, with respect to the wireless sensor network, previous approaches relied on "dedicated" networking, based on IEEE 802.15.4 /ZigBee protocol. Such choice provides for low power consumption and simple network management. However, in practical deployment occurring in mentioned projects it turned out that the approach, although fully functional, does not lend itself to easy installation, suitable for unskilled end-users. In particular:

- due to the limited transmission range of ZigBee devices, and depending on the actual home geometry, the signal coverage over the home domain need some accurate design. Usually, multiple antennas are needed, to be sensibly placed in the home environment. Although some conservative rule of thumb can be given, the variety of home topography makes it difficult to provide surefire general installation prescriptions.
- More generally speaking, installing and maintaining a new (dedicated) network may result too demanding for planned use-cases (which include self-installation scenarios) contradicting the NOAH "mission" statement and discouraging the technology adoption.

Therefore, we headed for a different approach, and decided to undertake a full redesign of home sensors, featuring better usability, scalability and lower costs. As described in D1.2, we pursued a "no new network" approach, and built the sensor network upon the mainstream home networking technology (i.e., Wi-Fi). Home devices connect straightforwardly to the Internet, with no need of “home gateway” or local aggregator. Installation is made extremely easy, by exploiting a plug and play approach, based on the Wi-Fi Protected Setup (WPS) mechanism. Wi-Fi communication range is much larger, so that in most cases an appropriate radio coverage is guaranteed by a single access point. The overall technology approach is therefore flexible, scalable and usable. Also, it represents an innovative solution, fully compliantly with the Internet-of-Things (IoT) paradigm.

Updated Description of Work

However, once assessed feasibility and soundness of the approach, a number of technical challenges had to be overcome, this requiring a reorganization of the workplan, summarized in the Gantt diagram below.



In the diagram, gray boxes refer to updated plan, whereas pink boxes show original schedule.

Basically, a longer timeslot has been allocated for the development of networking infrastructure (T1.2) and of the home kit (T1.3), in order to deal with technical challenges implied by the updated vision.

Updated tasks include the design of the cloud-based infrastructure, which is based on a commercial, mainstream cloud technology (IBM Bluemix). Home devices connect to the cloud and deliver data to a clod-based database, which in turn feeds the Behavioral Analysis Model (BAM). BAM outcome eventually support end-user apps: a couple of apps have been designed, aimed at the end-user himself and at (formal/informal) caregivers.

Consistently, pilot execution has been postponed and some testing procedures have been introduced, to validate newer components. In particular, actual pilot start has been delayed by about 6 months, and a technical testing phase has been introduced. At the time of writing, actual pilots have been started in Italy and Romania, whereas Belgium is about to start and is still involved in technical validation.

Although rescheduled, we still keep the 2-phases organization of pilot execution as planned. The first phase will provide technical validation, populate knowledge base for BAM refinement and give re-design feedbacks.

Checkpoint at the end of Phase 1 has been rescheduled accordingly, as well as Deliverable release and milestones plans.

Project month	*Calendar Month*		*Del. no.*	*Deliverable name*
3	AUG	2016	D1.1	Base technology report
3	AUG	2016	D2.1	Research and Concepting Plan
3	AUG	2016	D5.1	Set of guidelines
3	AUG	2016	D5.2	Dissemination plan
4	SEP	2016	D2.2	User Research Report
6	NOV	2016	D2.3	Concept Report
6	NOV	2016	D3.1	Criteria for selection of test sites / **Replaced by Pilot Manual**
6	NOV	2016	D5.3	Website and initial dissemination material
8	JAN	2017	D2.4	Service Specifications -
12	MAY	2017	D1.2	First technology report
12	MAY	2017	D5.4	First Calendar year report
15	AUG	2017	D1.3	Behavioral Analysis report
16	SEP	2017	D3.2	Evaluation material
18	NOV	2017	D4.1	Draft Business Plan
18	NOV	2017	D5.5	Mid-term report
20	JAN	2018	D3.3	Mid-pilot feedback report **- Postponed to M26**
24	*MAY*	*2018*	*D2.5*	*Refinement Recommendations -*
24	*MAY*	*2018*	*D5.6*	*Second Calendar year report*
25	*JUN*	*2018*	*D1.4*	*Second technology report*
32	*JAN*	*2019*	*D4.2*	*Plan of dissemination and exploitation activities*
35	*APR*	*2019*	*D4.3*	*Final Business Plan*
36	*MAY*	*2019*	*D3.4*	*Pilot final evaluation*
36	*MAY*	*2019*	*D5.7*	*Final report*

With reference to the deliverable list, just a slight modification was needed, postponing D3.3, supposed to be released after pilot phase 1 completion. A six-month delay has been accounted for, consistently with the pilot new schedule. A minor modification regards also D3.1, initially conceived as just reporting “Criteria for selection of test sites” and subsequently expanded to include a wider set of practical information for pilot implementation (“Pilot manual”). This is actually a dynamic document, to be updated and completed based on actual pilot execution. A minor adjustment also concerns D5.4 (First Calendar Year Report), which was mistakenly labeled as “public” and is to be considered as restricted to partners instead.

The updated milestone list is reported in the table below: changes are related to pilot rescheduling, as mentioned.

No.	*Milestone name*	*WP involved*	*Expected date* *(project month)*	*Means of verification*
M1	Service creation	**WP2**	8	D2.2, D2.3, D2.4,
M2	Pilot phase 1 start	**WP1**, WP3	15	D1.2, D3.1
M3	First pilot assessment	WP1,**WP3**,WP4	25	D1.3, D3.2, D3.3, D4.1
M4	Pilot phase 2 start	**WP1**, WP2, WP3	28	D1.4, D2.5
M5	Second pilot and market perspectives assessment	WP3,**WP4,**WP5	36	D4.3, D3.4

Workpackage achievements

In the following, a short summary of main workpackage activities is given, highlighting major achievements and problems (if any). Further details are available on relevant deliverables.

WP1 - Technology

Due to the above mentioned reasons, WP1 had a prominent role in the activities so far, which regarded the following areas:

- **Infrastructure:** a mainstream approach was pursued, integrating NOAH services within standard and widely diffused solutions. At the home level, Wi-Fi networking was exploited, avoiding the installation of dedicated networks and of gateway devices (other than the standard Wi-Fi modem-router). At the cloud level, commercial solutions were exploited, taking advantage of inherent security, interoperability and scalability of such solutions. Namely, IBM-Bluemix cloud was adopted as the infrastructural backbone, connecting all NOAH system components (sensors, interfaces, BAM). The IoT Platform was employed to connect the sensors to the cloud, the MySQL Compose service to store all the data used by the NOAH system and web services were developed using the Node-RED programming tool that run on Node.js. The whole chain is already in place and working.

- **Sensors:** as already mentioned, a complete redesign of home sensors was carried out, adopting native Wi-Fi communication and conceiving such devices as independent, smart IoT objects. Communication toward the cloud exploits standard MQTT protocol, allowing for better interoperability in IoT scenarios. Main issues to be overcome were related to the power consumption: Wi-Fi protocol attains large indoor ranges and high data-rates at the cost of higher power consumption, with respect to other home-networking solutions. A thorough optimization work has been carried out, leveraging hardware features and allowing for extending battery lifetime to values comparable with competing technologies.
- **User interfaces:** mobile applications were adopted as human-machine interfaces with the NOAH system. There are two distinct mobile applications: one for the end-users and one destined for the caregivers, both developed for the Android operating system. The designs of the interfaces were planned with simplicity and ease-of-use in mind, so they can offer quick access to relevant data in a pleasant and easy-to-understand way (graphical, icons, color-scheme, etc.) The designs were updated according to the reactions received from PSTs and the result of co-creation process. The information shown by the mobile applications is retrieved from the cloud through the exposed endpoints of the developed web services. Through these applications, the users can personalize their experience and their account information. Besides the state of the sensors, the applications also convey alerts/notifications regarding the physical state of the sensors (technical alerts), alerts concerning the safety of the end-users (e.g. forgot open door) and notifications regarding the well-being of the end-users, as detected by the BAM module.
- **Data analytics:** the adoption of indirect (i.e., behavioral) monitoring of daily living as a health/wellness indicator strongly relies on the possibility of extracting meaningful information from raw sensor data. This is made difficult by the wide variability of human behavior (which rules out the adoption of

fixed-threshold approaches) and by the need of providing such information in a clear, understandable fashion, not relying on technical skill of the (primary or secondary) end-user. Therefore, an adaptive approach, suitable for detecting relevant trends and anomalies has been devised and implemented, based on advanced machine-learning techniques. Through such an approach, meaningful information is automatically extracted from data patterns, suitable for being brought to the end-user in a simple and intuitive fashion: simple anomaly and trend indicators are worked out, relieving the end-user/caregiver from most interpretation burden and allowing for easy integration in common caregiving practices. A toolbox of many different "algorithms" has been developed and implemented within the cloud environment, which can be queried by services in a straightforward fashion. Such tools have been tested on real data (coming from other projects) and are online in the NOAH pilot environment, currently dealing with the "learning phase" for beta-test pilots.

WP2 - People-centric service design

WP2 conducted several workshop sessions to define project needs in terms of users and service design.

In particular, from the end user perspective, the traits of personas to be involved were defined. Generally speaking, the end users will be 60+ years old persons, men or women, all leaving alone and keeping regular contacts with at least one informal caregiver. Within such target group, two sub-groups were identified:

- Subjects with mild, incipient cognitive impairments ('sometimes I forgot something'). The level of the impairment will be assessed using the MMSE scale (mini-mental state examination) and the KATZ scale
- People with reduced mobility or using walking aids

The modalities for the design of co-creation session were defined in several meetings, better defined in deliverables D 2.1, D 2.2. Essentially, end users' and caregivers' involvement will be capital to drive the entire innovation process. At the time of writing, the organization of co-creation sessions was postponed to a later stage in the pilot test, in order for all users to experience the full production sensor set. After technical and beta testing of the sensors, a co-creation session will be held to identify expectations of (informal) caregivers regarding data translation and interpretation. For example, users will be asked to contribute to define how the platform or application should look like, or how data should be displayed. Furthermore, during beta-testing, feedback from the users will be monitored and analyzed in order to fine-tune the test scenario.

From the service design perspective, the main specifications of the user interface were defined, as detailed in D 2.3. Essentially, three different templates are adopted:

- End-user app, consisting of basic information and alert events (e.g. door open since too long)
- End user relative app, providing same functionalities and some notifications on detected behavior changes (e.g. sleep patterns)
- Caregiver app, providing all the above tools, as well as the possibility to have in-depth charts and stats

Technical details on the implementation of such interfaces are given in deliverable D 2.4.

WP3 – Validation

With respect to the original workplan, the introduction of a significant technology upgrade, involving innovative networking solutions, has led to a consistent revision of the pilot plans. In particular, we planned a more gradual deployment, to avoid stressing the end-user with possibly immature technologies. We therefore planned a first “technical” test, aimed at validating main choices and at assessing reliability. Such test was carried out at Trias/MobiLab facilities (i.e., testing was demanded to a partner not involved in technical development, to avoid any bias). Then, a “beta test” phase started (Pilot phase 1), which will allow for collecting real use data and to validate deployment and execution procedures. Finally, the largest scale pilot will follow (Pilot Phase 2).

For the validation, there were accomplished sets of criteria for cloud access assessment, data analysis (databases structure and homogenity) - with test datasets, and a ticketing system for diagnose and performance monitoring of pilot services installation and running.

For the selected IoT cloud platform, there were validated the rules and actions triggered by device data in real time - for a better relevance of this evaluation it was chosen an open source analysis and viewing platform.

As both relational and non-relational databases were implemented, validation of their scalability and homogenity performance benchmarks took into consideration large volumes of rapidly changing structured, semi-structured, and unstructured data, in geographically distributed scaled-out architectures (without any administration trade-off) having virtually unlimited capacity on demand. Test datasets were used for consistency evaluation with dedicated web-based isolated and platforms, secured via access control lists, vulnerability and error management for a complete data integrity assessment.

Synthetic test panels (with display cards showing availability, status and average timing) were used for response time and user interaction emulation.

Verification of compliance with the functional requirements upon commissioning of 1st pilot services was heuristically planned through evaluation under normal operating conditions (taking into account roles/tasks - specific maneuvers corresponding to each category of users in the work scenarios) as well as under network congestion or under partial connectivity. Performance scores were accomplished with a dedicated tool for metrics annotation. The associated ticketing system was chosen to manage incidents (being triggered by alerts and notifications), to enable monitoring of ticket status and solving time and to statistically determine prioritary improvements needed.

The adoption of the ABAS II questionnaire as an evaluation tool was considered and tested upon a consistent users sample in Romania. The areas that are being investigated are: Communication; The use of community resources; Functional behaviours learned in school; Family life; Health and safety; Leisure; Self-care; Social behaviour. The questionnaire results are included in an individual report for each end-user, where the individual strengths and / or weak points are determined.

The results of the questionnaire are to be discussed together with the caregiver to identify the current state of behaviours used in daily activities for the end-user. Following discussions with the caregiver and the end-user, some activities will be proposed to improve certain behaviors. Integrating this assessment by including caregivers' feedback in the project aims to objectively investigate the behavior of individuals and improving the daily behavioural areas that could make their lives easier.

WP4 - Roadmap to market

The aim of WP4 is to develop appropriate guidelines and marketing strategies for the introduction of the NOAH-Solution in the EU market. For this purpose, a business plan and a sustainable business model have to be developed. Particular attention was paid to the harmonization of the market approach with a national context.

Thus, in Task 4.1 (M1-M6) was researched on the Internet and with collaboration of the project partners, the various care service models identified and explored the possibilities of the NOAH solution in private/public organizations and authorities.

In parallel, a small survey was also conducted in the partner countries to get general opinion on the NOAH project, AAL technologies and the willingness to finance.

A further step was to query the financial affordability of a NOAH-Solution by end users and / or care organizations. Appropriate economic data, such as pensioners, household income, purchasing power a.s.o. were collected and compared to a provisional NOAH sales price. A presentation of the intended steps took place already in the KickOff meeting in Parma, (IT) on 16.06.2016. In the second project meeting - 2nd General Assembly (GA) - in Brasov, (RO), the results of the constraints were presented. The continuing activities as defined in Task 4.2 "Development of a Draft Business Plan" (M7-17) was the preparation of all necessary steps to develop a draft business plan. As recommended in the Guidelines 2015, the CANVAS Business Model (BM) was chosen as a starting point. For this purpose, two CANVAS workshops were visited in St. Gallen and Brussels.

After extensive preparatory work, a workshop with the project partners was carried out in the third project meeting - 3rd GA in Graz 8.-9.June 2017. The last months have been used intensively to design the procedural on a market entry with the NOAH product. A first version of a "Market Entry Structure" was prepared and in the 4th GA in Parma, on 28.-29. Nov. 2017 presented to the NOAH consortium and discussed. All results are part of the deliverable D4.1.

WP5 - Management and dissemination

The consortium held regular meeting, interleaving general Assemblies with teleconferences. The following assemblies were held:

- Parma, June 16-17, 2016

- Brasov, January 26-27, 2017
- Graz, June 8-9, 2017
- Parma, November 28-29, 2017

General teleconferences were held on:

- August 17, 2016
- November 3, 2016
- November 14, 2016
- January 10, 2017
- March 28, 2017
- April 7, 2017
- August 4, 2017
- October 13, 2017
- November 17, 2017
- December 20, 2017

Besides the above meetings, further ones were held on purpose, gathering a subset of partners to discuss specific issues. A private workspace has been made available to partners at https://podio.com/aicodit/noah-main, to share notes and documents.

On the dissemination side, besides the plan described in D5.2, main tools have been set up: project logo and visual identity have been defined and the website is online at http://www.noahproject.eu/. Also a few technical/scientific papers have been published already, related to the NOAH activity:

- Sorin-Aurel Moraru, Liviu Pemiu, Delia Ungureanu, Florin Sandu, Adrian Moşoi, and Dominic Mircea Kristaly, “Integrating wireless sensors into cloud systems for ambient assisted living”, *IEEE, Control and Automation (MED), 2017 25th Mediterranean Conference on*, ISSN: 2473-3504, pag. 1106-1112.
- Sorin-Aurel Moraru, Delia Ungureanu, Cătălin Cristoiu, Dominic Mircea Kristaly, Ionut Moraru, “Home-based System for Elderly Assisted Living”, *RICCES 2017, International Conference on Research and Innovation in Computer Engineering and Computer Sciences*, Malaysia Technical Scientist Association (MALTESAS), to be published in Journal of Telecommunication, Electronic and Computer Engineering (JTEC) (ISSN 2180-1843).
- Florin Sandu, Dan Nicolae Robu, Paul Vlad Fernoaga and George-Alex Stelea, “Tele-measurement with Virtual Instrumentation using Web-Services”, *IEEE 23rd International*

Symposium for Design and Technology in Electronic Packaging, SIITME 2017, ISBN: 978-606-551-089-0.

- Bassoli, M., Bianchi, V., De Munari, I., & Ciampolini, P. (2017). An IoT Approach for an AAL Wi-Fi-Based Monitoring System. *IEEE Transactions on Instrumentation and Measurement*, *66*(12), 3200-3209.
- Marco Bassoli, Valentina Bianchi, Ilaria De Munari and Paolo Ciampolini, “An Unobtrusive Wi-Fi System For Human Monitoring”, *IEEE International Conference of Consumer Electronics (ICCE 2017)*, Berlin.