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Conceptual MDVO Applicability to Aquaculture Food Tracing

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Abstract

As grid systems are organizationally best represented by the virtual organization concept, mobile grids are reflected by mobile dynamic virtual organizations (MDVO). Mobile grids are assumed to leverage a next-generation business grid infrastructure targeting at service provisioning for mobile and nomadic users. Accordingly, commercial prospects of potential MDVO application fields need to be investigated. This report introduces relevant mobile grid characteristics and gives insights into Norwegian aquaculture as a potential market for commercial mobile grid services. Based on the determined set of key requirements, an MDVO applicability assessment is conducted for Norway's aquaculture food tracing domain.

1 Introduction and Motivation

Grid computing is in use today in many areas, both in research projects and for business purposes. Current grid systems are typically deployed in order to solve computationally demanding or data-intensive tasks by leveraging the concept of resource coordination across administrative domains. In order to increase pervasiveness, next-generation grid systems will facilitate the adoption of grid computing principles within new fields. This includes in particular a shift from pure high-performance computing domain towards knowledge-intensive problem solving for mobile or nomadic end users. Mobile grids, thus, show business potentials for actors in the mobile telecommunications ecosystem.
Embedded in the joint exploitation efforts between the three Akogrimo [1] project partners Telenor R&D, University of Hohenheim, and University of Zurich, the idea to apply mobile grid concepts to aquaculture food tracing has emerged. From an organizational viewpoint, mobile grids are reflected by the virtual organizations (VO), extended by mobility and dynamics aspects, resulting in mobile dynamic virtual organizations (MDVO). The technical report at hand investigates in the general applicability of an MDVO to the domain of aquaculture food tracing. In particular, Norwegian aquaculture has been selected as the specific application domain. This is motivated by Telenor's established know how in supporting Norwegian fish farming by means of information technology, University of Hohenheim's plan to pursue future European research projects in agro food tracing, and University of Zurich's expertise in MDVO concepts.
The applicability assessment conducted in Section 4 provides the preliminary answer to whether MDVO concepts are meaningful to be applied in Norwegian aquaculture food tracing. This answer is based on the respective introduction to mobile grids and MDVOs (*cf.* Section 2) and Norwegian aquaculture (*cf.* Section 3).

2 Mobile Grid and MDVO

This section introduces grid computing and its evolution over the past years in order to outline relevant mobile grid characteristics. Those attributes lead to the development of the key set of MDVO applicability requirements to be adopted in Section 4.

2.1 The Evolution of Grid Systems

The concept of grid computing first appeared in the 1990s. From then, grid systems have undergone considerable evolutionary steps, while the development and integration of new concepts takes place within several grid-related research projects. The EU project Akogrimo, for instance, blueprints such a next-generation grid — the mobile grid.
Mobile grids provide a service delivery platform that is designed for the provision of commercial mobile grid services across several administrative domains in order to solve complex problems for mobile or nomadic users. Figure 1 documents the main evolutionary steps for grid systems over time.
Those steps include traditional grid computing, service grids, and next-generation grids, *i.e.*, mobile grids in this context. In accordance with the detailed discussion conducted in [6], the mentioned three grid categories are subsequently summarized in short.

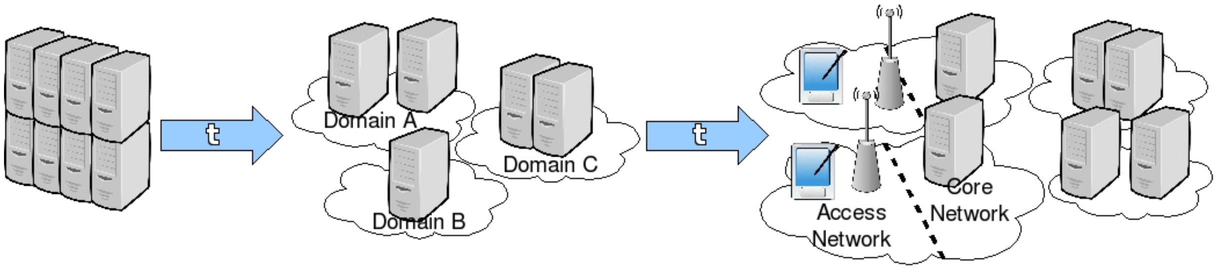

Figure 1: Grid Evolution from Grid Computing over Service Grids to Mobile Grids

2.1.1 Grid Computing

Traditional grid computing focused on high-performance computing. It aimed at solving computationally or data-intensive tasks by building clusters of relatively inexpensive computers that are interconnected by network technology. Such grids were typically deployed in non-commercial, research-oriented environments and within one administrative domain.

2.1.2 Service Grids

Service grids introduce two main extensions over traditional grid systems. First, resources are virtualized by means of a service layer — technically spoken web services with certain extensions, in combination being named grid services. Second, and leveraged by introducing a service layer, multi-domain grid service provision becomes possible. Sharing and coordinating resources across administrative domains is reflected by the concept of virtual organizations (VO).

2.1.3 Mobile Grids

Mobile grids aim at expanding grid concepts to mobile nodes. In a mobile grid, not all resources have to be mobile, but mobile grids support various forms of mobility, such as device, user, and session mobility so that, for instance, a running multimedia streaming service can be transferred from a mobile device to a larger display without service interruption, but with an adapted service quality and service accounting.

Mobile grids, thus, are challenged by sharing higher level resources, such as knowledge in terms of device and user context and adaptive business process execution depending on current context information. In short, mobility drives dynamics in the VO. In order to stress these important extensions, the rather static VO concept is complemented by the introduction of mobile dynamic virtual organizations (MDVO) [7].

2.2 Applicability Requirements for MDVOs

At this early stage in joint exploitation the basic set of key factors for successful application of MDVO concepts needs to be determined. The applicability assessment performed in Section 4 is based on this set of factors. Its result forms the main decision criterion for University of Zurich whether or nor to further pursue joint exploitation as originally envisaged.

Accordingly, this section only determines success factors that are perceived to be of central importance and, thus, are crucial to each and any mobile grid implementation. Even though neither confirmed nor reliable estimations on the investments needed to deploy and operate mobile grid systems exist, considerable expenses, both in infrastructure and human resources, are highly probable to be faced when actually implementing a mobile grid. This is mainly due to the level of complexity mobile grids come with.

MDVOs envisage mass consumer markets, are commercially oriented and need to solve many cross-layer as well as multi-domain service provisioning issues in order to offer finally a mass customization solution. These challenges clearly indicate that high investments will be needed even if Akogrimo (prototypically) implements a mobile grid. From an organization model viewpoint, MDVOs extend the VO concept by a strong focus on mobility and dynamics. Further, it has been stated that mobility appears as the key driver for dynamics [6].

Consequently, the applicability assessment will be pursued on mobility and dynamics, whereas mobility support takes a higher relevance grade. As a third, more basic criteria, multi-domain commercial service provision in a VO needs to be evaluated, since mobile grids rely on the concept of resource sharing across domains, as service grids also do.

2.2.1 Mobility

Making device, user, or session mobility as well as pervasive access a reality imposes considerable ef-

forts. Consequently, users of a mobile grid need to exploit mobile grid service provision at full — otherwise the efforts taken most probably will not pay off. In economic terms expressed, mobility is required to allow for value added higher than related costs.
Mobile service usage and service provision is related to nomadic use. Mobile and nomadic usage schemes need to be separated however. In nomadic environments, users or providers change also locations, but they do not consume or provide services while moving. They rather use/provide a service at one location, suspend or terminate the service, change locations and then start using/providing services again.
Furthermore, different mobility types have to be considered: Device, user, and session mobility are used synonymously to terminal [5], personal [4], and session mobility [5], respectively. *Device mobility (terminal mobility)*, as visualized in Figure 2, enables terminals to move from one IP (Internet Protocol) subnet to another without session or service interruption.
With *user mobility (personal mobility)*, depicted in figure 3, a given user can access a service or session at different terminals, whereas these devices form a group of devices with respect to logic addressing. The group is addressed by one logic address (1-to-many addressing scheme). Moreover, this scheme is combinable with many-to-1 addressing where various addresses map to one logic address (as mentioned before).
Session mobility (see Figure 4) enables users to keep sessions when moving from one device to another. At first sight, this seems to be very similar to user mobility. However, in session mobility, sessions are actually only accessible on a single device at a time so that sessions are transferred completely or in parts only to another terminal. For instance, a video stream could be transferred from a mobile terminal with a small screen to a beamer within reach.
Those mobility types are combinable, such as in the way that users, for instance, can change access networks and terminals while services remain available (service mobility [5]). With regard to the applicability assessment (*cf.* Section 4), a high mobility type combination is aspired. Further, mobility preferably shall act as a product enabler rather than a product supporter.

2.2.2 Dynamics

Dynamic virtual organizations (DVO) can be established with or without mobile grid nodes. Dynamics in non-mobile grid systems relates to dynamic organizational constitution and to dynamic process execution based on current needs. The same concepts apply to mobile grids, whereas mobility is assumed to raise a much higher dynamics level, since hand-offs and hand-overs with regard to previously described mobility types will take place.
Consequently, the organizational composition on the mobile grid node side will change often. This rises complexity since sessions and provided or consumed services are required to handle these new assumptions on availability and mobility-related features of mobile nodes. On the other hand, mobility is seen as the key driver for a high number of context elements. Context originates and has to be handled in an integrative manner from network to application. Changed context asks for highly flexible business process execution mechanisms so that, for instance, new grid service providers need to be bound to the VO according to current device or user context.
Dynamics are perceived on the one hand as the key driver for customized products, while, on the other hand, dynamics technically are a challenge. Similar to the mobility-related applicability requirements, dynamics needs to offer considerable value added in order to justify the application of MDVO concepts to an envisaged domain.

2.2.3 VO

Multi-domain service provisioning and resource sharing across domains determine the main concepts in current and future grid systems, and with that, also in mobile grid computing. A domain suited for grid computing, thus, must be characterized by a high number of legally independent actors — in terms of organizations consisting of legal or natural persons — that profit more from sharing their resources and aggregating basic ser-

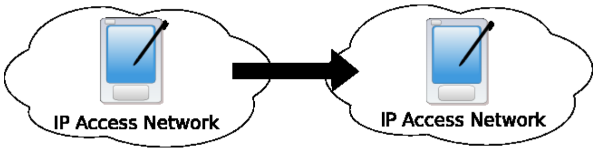

Figure 2: Device Mobility (Terminal Mobility [5])

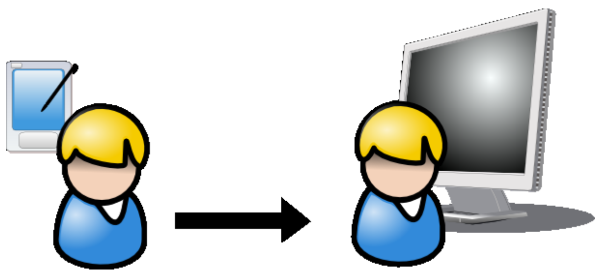

Figure 3: User Mobility (Personal Mobility [4])

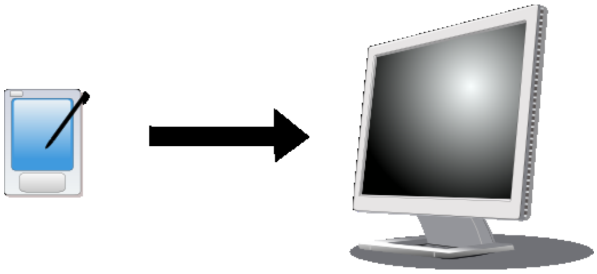

Figure 4: Session Mobility [5]

vices into complex services than direct and indirect costs incurred with implementing and operating a grid solution. This requirement implies that various views on business-related data for domain-internal use, *e.g.*, for accounting purposes, and inter-domain information exchange, *e.g.*, for transferring charging records, need to be available.

3 Norwegian Aquaculture

This section gives an overview of the fish farming industry in Norway. It outlines basic insights into the the sector and its value chain steps, summarized from [3]. Moreover, it presents the relevant European regulation on food law and food safety that plays an important role in triggering the primal idea of applying MDVOs to aquaculture.

3.1 Basics About Norwegian Aquaculture

Fish farming is Norway's third largest export industry after oil and gas industry. Norway with its long coast line, large fjords and access to the Gulf Stream provides optimal conditions for fish farming. With the overall goal of sustainability in mind, aquaculture requires a healthy environment in terms of maritime safety, which potentially collides with the interests of the oil and gas industry with respect to discharges to the sea.

Two species are mainly raised today with a 41% share in Norway's fish exports, namely arctic salmons and rainbow trouts. Current research is ongoing in order to broaden fish farming towards other species such as cod (which is highly demanded on the market), white halibut, arctic char, or blue mussels. The fishes are exported to more than 100 countries, with Japan being one of the most important buyers. In 2004, the exports of arctic salmon and rainbow trout went over 600000 tons, which makes Norway to be one of the biggest salmon producers in the world.

Aquaculture in Norway has its roots in the 1960s. Over time, several optimizations took place solving issues like insufficient food, overpopulation, and poor placement of the fish cages. The fishes themselves are raised in mobile, but anchored bag-like nets that are 40-50 m deep and range from 60 to 160 m in circumference. In maximum, 2.5 kg of fish per m^3 water are allowed, which corresponds about to the optimal ratio between fishes and water volume so that salmons feel comfortable.

Besides the nets with the fishes, fish farming sites nowadays feature automatic feeding devices, over- and under-water monitoring equipment, and anchored platforms that are targeted to other infrastructure, mostly for the personnel. With regard to strict quality control, aquaculture is highly regulated, so that sites to be used for fish farming not only need to be approved by the respective authorities, but licensing conditions assure that a site is fallowed for some time after a fish generation has lived in it.

3.2 Fish Farming Value Chain

Salmons in average need 20-30 months to grow from roe to slaughter-ready weight of about 4 kg. The fishes are released into sea water at the age of 10-12 months. In order to put on 1 kg of weight, farmed salmons need approximately 1 kg of feed which is extremely efficient compared to other breeding animals. The fish food itself, totaling in about 50% of the operating costs for fish farmers, consists of fish meal that traditionally is gained from marine raw material, but newly also integrates vegetable raw materials from agriculture. The fish meal's main ingredients are fish oil, minerals, fibers, and vitamins (astaxanthin, responsible for the red color, originating from mussels). The process from roe to the end product embraces several life phases as shown in Table 1.

In accordance with the shown life phases in 1, figure 5 depicts the current value chain in Norwegian aquaculture, including relative values for the year 2004 with respect to each step's contribution to value creation. In absolute numbers, the estimated value creation over all steps in 2004 amounted to 13.7 billion NOK. The value chain presented in 5 does not cover the complete set of value adding steps from roe to the consumer. It is fish farming centered and, thus, misses the downstream value chain steps of refinements, logistics and retailer activities.

3.3 European Food Law

Mainly with consumer protection, informed choices, and human or animal health in mind, the European Union (EU) issued in 2002 regulations on food

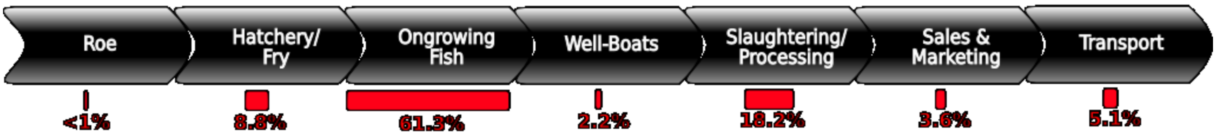

Figure 5: Relative Value Creation in Norwegian Fish Farming (2004, adapted from [3])

Table 1: Salmon Life Phases and Breeding Locations [3]

Life Phase	**Duration (Months)**	**Location**
Insemination (roe, milt, and water)	0-2	Hatchery
Yolk-sac fry (self-feeding)	2-3	Hatchery
Fry, fingerling (physical transformation towards life in sea water)	3-11	Hatchery
Smolt, ongrowing	11-20 (up to 30, depending on growth rate)	Sea cages

law and food safety in particular [2]. This regulation aims at harmonizing the various different applied principles and procedures within the member states. Food safety includes requirements enacted on feed for food-producing animals, thus, also relevant for feed suppliers in fish farming and aquaculture in general.

Fish farming is explicitly mentioned within the regulation (*e.g.*, [2], motive 13). Provisions target the complete value chain with all involved stakeholders to be satisfied and to be guaranteed safe food. The envisaged level of food safety is applied independently from whether goods are traded on the internal or on international markets. Norway, not being a EU member state, will be affected by these regulations indirectly. However, it is assumed that EU determinations on food safety will show effects on national regulations in order to establish compliance with EU food law.

The EU stresses its intention to foster food safety also on an international level, for instance by means of international trade agreements. Countries that are not members and that have concluded contracts with the EU, forcing them to enact EU regulations with respect to food safety, are allowed to participate in the EU regulation process.

The general risk analysis method to be applied consists of the following components: Risk assessment, risk management, and risk communication. In order to have relevant food safety-related information at hand, measures throughout the value chain have to be taken. This has to be supported by a comprehensive traceability system. The minimum level with respect to traceability is determined in the way that at least the supplying companies can be identified for each value chain stage. The main responsibility for ensuring food safety lies within the food business operator and — with respect to feed safety — within the feed business operator, respectively [2], Art. 19 & 20.

Food business is defined as "any undertaking, whether for profit or not and whether public or private, carrying out any of the activities related to any stage of production, processing and distribution of food" [2], Art. 1. Accordingly, food business operators are defined as "the natural or legal persons responsible for ensuring that the requirements of food law are met within the food business under their control" [2], Art. 1.

A European food safety authority is appointed in order to reinforce existing food safety systems. The authority takes on the tasks of risk assessment and risk communication. It also coordinates the system for collection and analysis of relevant data. The regulation foresees January 1, 2007 as the time frame until compliance with its determinations need to be established. With regard to traceability systems to be in place, the regulation determines the following provisions [2], Art. 18:

- "To this end, such operators shall have in place systems and procedures which allow for this information to be made available to the competent authorities on demand."
- "Food and feed business operators shall have in place systems and procedures to identify the other businesses to which their products have been supplied. This information shall be made available to the competent authorities on demand."

In order to recognize and react to critical situations in a short time frame, a rapid alert system needs to be established. Its main tasks are found in the analysis of received data and in providing the Commission and the member states "with any information required for the purposes of risk analysis" [2], Art. 35. Both, the system for collecting and analyzing data on food safety as well as the rapid alert system face challenges in the area of confidentiality. In general, the authority is bound not to release any confidential information to third parties, except from information that must be made public [2], Art. 39. This includes explicitly "information, available to the members of the network, relating to a risk to human health" [2], Art. 52. Such information needs to be publicly available.

In the case of emergencies, a so-called general plan, covering procedures to deal with the crisis, is enacted. Further, a crisis unit is established. Its main tasks embrace the collection and analysis of current information and the accurate communication towards the public. It "may request the assistance of any public or private person whose expertise it deems necessary to manage the crisis" [2], Art. 57.

4 MDVO Applicability Assessment

The EU regulations on food law and food safety presented in Section 3.3 clearly determine the time frame and the mission for setting up an information technology-supported system that implements these provisions. The question is whether mobile grid and, thus, the MDVO are suited concepts to satisfy this need.

The methodology used to answer this question from a conceptual angle consists of assessing values for involved stakeholders created on the respective levels of VO, dynamics, and mobility as introduced in Section 2.2. This leads to a final conclusions section which determines from the perspective of University of Zurich the basic decision criterion on whether or not to pursue joint exploitation efforts in the envisaged way.

4.1 VO Assessment

In the aquaculture food tracing scenario, a multitude of stakeholders is identified. Stakeholders consist of three main groups: Authorities, consumers, and feed/food businesses. These three groups can profit from sharing resources in a grid in order to leverage food safety over the complete value chain.

Authorities take an aggregating role within this service grid. Authorities comprise the European food safety authority as a central instance running the grid platform, but also authorities on national member state or associated state level. Authorities form the grid core. They provide data storage grid services as well as analysis grid services to VO members either directly or sourced from dedicated grid service providers.

In normal operation phase, the various feed/food businesses are bound to the VO regularly. They provide value chain step-related information grid services to the authorities and to downstream food businesses while they consume information grid services from upstream feed/food businesses. Exchanged information is aggregated from operational data collected within the administrative domain in question. It documents at the minimum level the way through the value chain. If needed it can be altered by more detailed information such as measured temperature during a transport from one facility to another. In normal mode, feed/food businesses, however, are not requested to release any business-critical, thus confidential, information, neither to authorities nor to other feed/food businesses.

National authorities are also bound to the VO periodically in order to exchange current status information which is achieved by means of an information grid service provided by the European food safety authority and — if national authorities collect, analyze, and aggregate food safety-related information on national level as well — by national authorities. Consumers as the third stakeholder group can use a food safety information service provided by the authorities. This service, however, is presumably not a grid service that is consumed directly as such, but rather via a web portal that allows for information presentation suited to mobile and non-mobile devices.

In emergency operation phase, after the rapid alert grid service has been invoked, authorities collocate members of the crisis unit. Team members are recruited on the one hand from a core set of experts that publish presence information to the rapid alert system via a mobile grid service. On the other hand, local experts, *i.e.*, in the region a crisis has been detected, are recruited, potentially located with the help of a grid service provided by national authorities to the European central authority. At this stage, Commission members and other, not directly affected national authorities are informed and continuously updated about the current situation by means of an alert grid service. The European authority acts as the communication central towards all stakeholders. Further, it coordinates the crisis unit's mission on scene.

Unit members are equipped with mobile devices. Team members are able to undertake measurements and further analyses on scene. They are provided with up-to-date information from the central authority and they gain access to the full operational data of the involved administrative domains, meaning affected feed/food businesses.

VO Assessment Conclusions

Investments and operational costs of such a service grid as described will be considerable. However, if food safety is realized by the EU as an indispensable strategic commitment, possible to be enacted bindingly for member states and all involved stakeholders, costs are of secondary, however, still not negligible nature. By grid systems' dedication to resource sharing across domains, inherent service-orientation, and by being based on open, standards-based technologies and protocols, service grids qualify as the optimal choice to implement such a service delivery platform.

4.2 Dynamics Assessment

The aquaculture food tracing scenario as described in Section 4.1 is characterized by many complex problem solving tasks. The scenario incorporates a high level of dynamics with respect to organizational composition, probably not on the consumers' side, but rather on grid service providers' side. Provided that consumers do not directly consume grid services, but are informed by means of web information portals, consumers are not perceived as DVO members. Consumers could install grid applications on their mobile or fixed devices. Diffusion and acceptance rates among consumers, however, are assumed to remain low. Even though these estimations base on assumptions only, the value added for consumers remains irreproducible when consuming grid services instead of accessing web portal information or information syndication, such as subscribing to a news feed.

Context in terms of food safety information and analysis results triggers dynamics with regard to business process enactment. The scenario embraces, for instance, two operation modes. One for normal and one for emergency situations. In either mode, but also to change modes, context from various, changing VO members is collected and continuously evaluated, whereupon executed processes are adapted or new processes are invoked. In emergency mode, a knowledge base — implementing the so-called general plan — is at hand to manage crises of different nature. In contrast to emergency operation mode, processes in normal operation mode are assumed to be of a more static nature, such as they are better predictable in their appearance. As the system needs to track and analyze potentially a vast number of feed/food traces of various operational DVOs, organizational dynamics are assumed to be a considerable challenge also in normal operation mode.

Dynamics Assessment Conclusions

Apart from consumers that rather consume non-grid information services, a high level in dynamics, both with respect to organizational composition in DVOs and with respect to business process execution is identified — the latter particularly being the case in emergency operation mode. Due to their focus on highly scalable and flexible electronic service provision across domains, service grids and DVOs appear as the optimal choice to implement an adaptive aquaculture food tracing solution.

4.3 Mobility Assessment

Mobility is envisaged mainly in two parts of the scenario, namely in feed/food transportation-related value chain steps during normal operation mode and in crisis unit activities during emergency operation mode. In transportation, device, user, and session mobility are possible. For example, a refrigerated truck could be equipped by temperature sensors, a mobile device for the truck driver, and a transceiver. Measured temperature values are transmitted in this scenario by means of near-field communications technology to the mobile device where data is continuously evaluated.

If a certain threshold is reached an alert is triggered and the truck driver is informed. If the truck driver is able to restore normal temperature conditions in the cooling chamber within a given time frame, the alert is stopped. Otherwise, the food business operator's logistics central is informed over-the-air and a voice communications channel is opened for further assistance. Moreover, the mobile device is able to record and transmit a video stream to the logistics central. If again a certain time limit is reached and no solution for the issue was found authorities are informed automatically whereupon the food business is able to report on further measures to be taken. The presented case outlines an example for device mobility.

As the main responsibility for food safety lies in the hands of the currently processing feed/food business, responsibility is carried forward, for instance, at the handing over of a batch of fresh fish from a transportation undertaking to a slaughterhouse. At that moment, session mobility takes place, since the current fish tracing session is transferred completely to the downstream organization — provided the newly responsible organization accepts the batch under the information provided by the upstream organizations.

Processes related to locating crisis unit members as well as unit operations on scene profit potentially from device, user, and personal mobility, or even a combination thereof, so that a given operation could be handed over to another unit member. Personal mobility is already possible in normal operation mode where potential unit members publish presence information, whereas multiple devices are used for this purpose.

Mobility Assessment Conclusions

Even without an outline of the complete set of possibilities for mobile usage schemes there is enough evidence that several options to apply various and potentially also combinable mobility types in a meaningful way can be identified within the aquaculture food tracing scenario. However, it remains highly doubtful, whether mobility or MDVO concepts provide for substantial value added in comparison to nomadic usage schemes. For the given examples, a comparable service quality is also achieved if users are able to resume consumed or provided services when being able to log on regularly as nomadic users. Mobility and MDVO concepts, consequently, are acknowledged as to provide for a higher flexibility over nomadic usage schemes, determining a product supporter but not a product enabler.

4.4 Overall Applicability Conclusions

Mobile grids as next-generation grid systems lack the comfort of expertise derived from case-specific implementations. This leaves only options to conduct applicability assessments based on *ex ante* assumptions and estimations. Irrespective of those limitations, and based on outlined assumptions, the qualitative analysis conducted has revealed a high potential for DVOs and service grids in the aquaculture food tracing scenario.

However, it was not possible to justify unambiguously the application of MDVOs and mobile grids to the domain, since mobility apparently provides for higher flexibility in many ways, but does not indicate obvious value added over nomadic schemes. Under the assumption that mobility causes higher design and deployment costs than nomadic use, a trade-off between flexibility requirements and costs has to be found.

In this context, the general applicability of MDVO concepts to aquaculture food tracing is accepted under reserve. Further investigations need to be undertaken on the costs incurred for full mobility support in order to allow for a concluding answer to whether continuation in this direction is worthwhile for University of Zurich.

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