ClusterWIS Revisited

An Updated Look at the Decentralized Forest Information and Management System

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***Abstract*—The cluster forestry and wood's major challenges are its structural complexity and heterogeneity, its many stakeholders, and its decentralized processes. The aim of the ClusterWIS approach is to overcome these challenges. Its core idea is the development of a novel forest information system based on a decentralized infrastructure integrating new planning and consulting methods and interconnecting existing decentralized work processes. It provides end-to-end encrypted communication to run the various processes and to supply them with data while using international standards throughout the system and keeping participation requirements low. The paper at hand gives details on the ClusterWIS communication infrastructure, its apps and services, and the reference applications as well as their realization in a comprehensive demonstrator.**

Keywords-forest information system; sustainable feedstock management; decentralized data management; secure communication; demonstrator.

I. Introduction

In [1], we introduced the idea of ClusterWIS, a completely decentralized forest information and management system that conveys principles of Industry 4.0 to the cluster forestry and wood. The conceptual framework of ClusterWIS has now been further developed in its communication infrastructure and implemented as a demonstrator for practice oriented test and promotion.

The cluster forestry and wood is the economic sector comprising all stakeholders from forest owners to forestal service providers and the woodworking industry. Its major challenges are its structural complexity and heterogeneity, a huge number of stakeholders with often contrary objectives, and decentralized processes. In the federal state of North Rhine-Westphalia (Germany) alone, 150,000 private forest owners own two-thirds of the forest (90% of which own less than 5 ha), and many small service providers (for planning, tending, logging, etc.) exist [2]. Furthermore, the "production plant" forest provides not only wood as its main product (used for building, paper or as a fuel) but also serves as a long-term CO_2 reservoir or as a recreation area. Altogether, this renders process optimization far more complex than in classical manufacturing industry.

Thus, for a sustainable feedstock management and an efficient wood and biomass mobilization throughout the cluster, the increasing demand for wood from sustainably cultivated forests need to be aligned with the requirements of climate change and resilience, environmental protection and society in general. For that purpose, the research project ClusterWIS (WIS for German "Waldinformationssystem" – Forest Information System) introduces novel planning and consulting methods. In order to implement these processes within a decentralized infrastructure, ClusterWIS adopts, refines and widely interconnects the crucial working processes within the wood and forestry sector.

Often, centralized approaches have been used to resolve the cluster's structural weakness. However, such approaches, contradict the highly decentralized organization that is typical for the whole sector. In particular, many conservative forest owners do not accept an obligatory centralized data management for reasons of data privacy (especially in Germany). For this reason, the foundation of the ClusterWIS approach is a novel, decentralized infrastructure based on standards for data modeling and data exchange. It provides end-to-end encrypted communication to run the various processes and to supply them with highly topical inventory and process data. To provide for the cluster's heterogeneity, it keeps the participation requirements for third party systems low. Furthermore, international standards are used throughout the system like Open Geospatial Consortium (OGC) web service standards, Geography Markup Language (GML) for data exchange in general, ForestGML [3] for *n*D temporal inventory data, ELDATsmart [4] for timber logistics data, StanForD [5] for forest machine data, or papiNet [6] for communication with the paper industry. However, the approach is open to any other formats and standards.

A ClusterWIS network (Figure 1) comprises applications and services as its nodes, connected by means of the secure communication infrastructure. Stakeholders use specialized desktop and mobile applications (e.g., for forest information, forest inventory, production planning etc.) or web applications (e.g., for forest owners, service providers etc.) to access this network. Specialized services, e.g., for processing remote sensing data or forest growth simulations, perform computationally expensive and data intensive tasks for a broad user group even on thin clients like mobile devices. Finally, services for administrative tasks like communication, cloud storage or registration build the network's backbone.

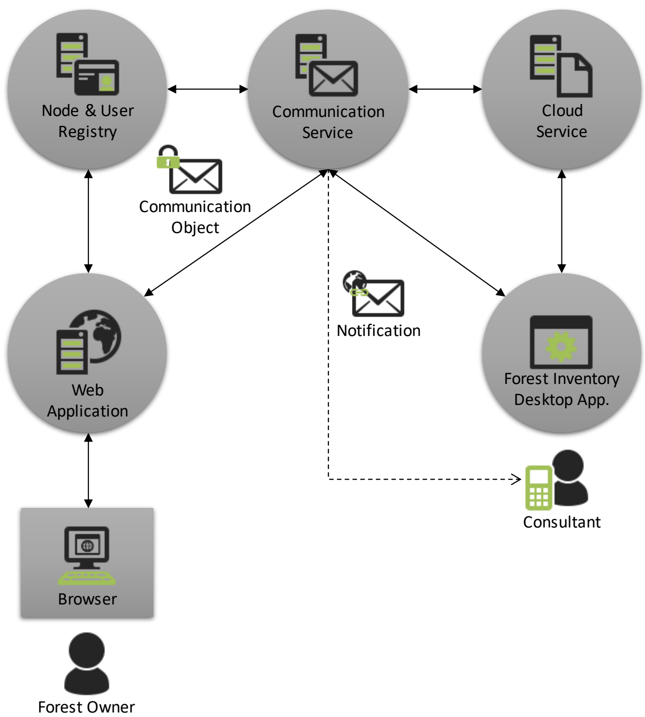


Figure 1. A ClusterWIS network consists of service and application nodes.

For the first time, this decentralized network allows for process optimization across the cluster. In the research project, eight interdependent reference processes (like forest information, planning, consulting, timber trade and production) are analyzed in detail.

The ClusterWIS concept can also be described in terms of four layers:

ClusterWIS Documentation: This layer provides the documentation of the service infrastructure comprising data standards, a common communication standard, and a common public key infrastructure (PKI). Furthermore, it contains best practices for data exchange (e.g., which formats to use), the usage of software services (e.g., for remote sensing data processing), and for offering services (e.g., consultation or forest inventory).

ClusterWIS Directory: While *ClusterWIS Documentation* yields a "common language", *ClusterWIS Directory* provides the necessary directory (or registry) of users and nodes. This includes the infrastructure for their registration, retrieval, and authentication – all needed for secure communication and data exchange.

ClusterWIS Notifications: In principle, the previous two layers suffice to realize and operate a ClusterWIS network. This third layer adds a communication infrastructure to further simplify data exchange between actors within the forestal domain (where senders and receivers are often offline) by buffering messages and by publishing notifications for them.

ClusterWIS Applications: This layer consists of the software solutions built on top of the ClusterWIS infrastructure. The focus is on extending existing software. For that purpose, the participation requirements are kept low (see previous levels). Such systems comprise locally installed management software (e.g., for forest inventory), web-based management software, platforms for data exchange or trading, and mobile applications.

The rest of this paper is structured as follows: Section II presents work related to our own and motivates the development of the ClusterWIS approach. Sections III and IV give more details on the ClusterWIS infrastructure and its communication approach. Sections V and VI introduce the ClusterWIS applications (desktop, mobile, Web) and specialized services while Section VII gives an overview of the reference processes analyzed in the research project. In Section VIII, we add a detailed look at the recently realized demonstrator and the yielded response. Finally, Section IX concludes this paper.

II. Related Work

ClusterWIS is built on its project partners' preliminary work. Important results come from the research project series Virtual Forest in general, its commercial spin-offs, the underlying SupportGIS technology, and the forest growth simulator SILVA [7]. ClusterWIS aims at making these results available to the whole cluster. Besides summarizing this work, this section introduces similar approaches developed by others.

A. The Virtual Forest

The ClusterWIS approach is built on the methods of the "*n*D Forest Management System Virtual Forest" [8], developed in the research project series "Virtual Forest". It provides the necessary technological framework as well as the basis for data modeling, management and distribution.

The idea of the Virtual Forest is a central database that manages all forestal data. It provides various applications for remote sensing data processing (tree species classification [9], stand attributes evaluation [10], or single tree delineation and attribution [11]), forest inventory, planning in biological and technical production, forest machine simulation for training, and support of the logging process.

The technological basis of the central database is the SupportGIS technology [12]. It is widely used for GIS related applications, is based on the standards of OGC and ISO, and powered by object-relational databases. It efficiently manages large amounts of data and supports exchange by standard OGC web services. Furthermore, data can be managed in *n* spatiotemporal dimensions [3], allowing to track and analyze forestal data over time.

The Virtual Forest uses ForestGML [3], a GML-based modeling language, to model forestal data on a consistent, OGC compliant basis. This facilitates its widespread usage and allows for the usage of OGC web services.

Central parts of the Virtual Forest system are already in use by two German state enterprises. While the Virtual Forest focuses on the usage in such large, homogenous enterprises, ClusterWIS aims at making these results available to the whole cluster by decentralizing the approach.

B. *Forest Growth Simulator SILVA*

Silviculture today has to consider a wide range of ecosystem services (ES) that earlier were considered a by-product of traditional forestry. Moreover, against the background of climate change, forest management has to maintain climatic resilience and stability through provision of an adequate forest structure. Thus, forest consulting increasingly applies forest simulation models to estimate the effect of various silvicultural pathways on productivity, quality and further ES [13] [14]. Such ES are carbon sequestration, biodiversity, recreation, and groundwater recharge. Yet, they typically stand within the particular focus of state forestry. However, private forest stakeholders today also advocate to foster the adaptation of such services by private forestry based on financial incentives [15]. The forest ecosystem model [13] is a preferential tool to take into account ES synergies and tradeoffs and to optimize among various silvicultural objectives. It allows forest consulting to compare scenarios that adhere to a sensible preselection of silvicultural pathways and to direct forest management towards the most effective subset of them. Such simulation models have primarily been applied within state forestry institutions that maintain the necessary IT infrastructure.

Within that scope, the forest growth simulator SILVA has been integrated into the aforementioned Virtual Forest system. SILVA implements the paradigm of a service oriented architecture (SOA). Its kernel is an independent application that does not expose any specific tasks but rather a wide collection of services that may be coupled and assembled to provide specific simulations or evaluations. Moreover, it provides its services through various types of interfaces that use international standards, such as the Simple Object Access Protocol (SOAP). Thus, it fits into a distributed environment as well as into a strictly local one. Within the Virtual Forest project, several scenarios that integrate SILVA both locally and as a remote service into the larger environment were implemented and tested.

C. *Similar Approaches*

Until now, others developed approaches similar to ClusterWIS. Some proprietary solutions are available, e.g., online platforms like “IHB Holzbörse” for timber trade [16] or the “Branchenbuch Wald und Forst” as a business directory for consultants [17]. The internet marketplace “CoSeDat" offers the possibility to exchange data and electronically signed PDF documents [18]. In Finland, UPM Paper offers “UPM Customer Online” [19], a digital service channel for customers. In summary, these approaches focus on specific aspects of the complex process chain, only. Hence, a permeability of shared data between the different processes is not given. Often, the idea was to develop centralized systems such as “virtual enterprises” [20], the “FOCUS-Platform” [21]. Another centralized approach is presented in the research project “GeProOpt_Holz” [22]. Similar to ClusterWIS, it aims at optimizing business processes in the cluster. However, as mentioned in the introduction, such centralized approaches are not accepted by many cluster actors.

Software solutions like “WaldPlaner” [23] already deliver functionality for planning and decision-making regarding sustainable forest management, but on their own they lack the necessary communication infrastructure and integration into larger processes. Approaches like the “Scottish Forest and Timber Technologies initiative”, supported by enterprises and industry, promote knowledge exchange and cooperation between enterprises in the sector [24]. They are successfully able to connect regional actors, but the knowledge is not shared more widely. The web portals “Wald in Österreich” [25] in Austria and “WaldSchweiz” [26] in Switzerland serve the exchange of information in the sector.

Thus, existing approaches already cover several of the cluster’s requirements. However, they lack an approach to connect its complex and decentralized structure and do not support a comprehensive execution of all the essential business processes from request to invoicing. This motivates the development of the ClusterWIS approach as introduced in Section I.

III. Infrastructure

The cluster’s achievable efficiency is strongly related to the way its actors communicate. This requires a framework that does not unnecessarily restrict an actor’s professional view or its organization’s structure. Thus, the ClusterWIS infrastructure is based on secure networking of so-called ClusterWIS nodes. These nodes can either be applications (Section V), specialized web services (Section VI) or services for administrative tasks.

To use its services and applications, any actor can register and participate in the ClusterWIS network. Well-established methods of IT security are employed to guarantee the safety of connections and exchanged data between actors, applications and web services. Client-side Hypertext Transfer Protocol Secure (HTTPS) is used for authentication and secure connections. It is integrated into a PKI that allows for end-to-end data encryption. Finally, authorization is based on GeoXACML (Geospatial eXtensible Access Control Markup Language) providing user rights on data and methods.

The administration of the ClusterWIS network is reduced to few central services:

- A node and user registry for all participating actors and nodes (applications and web services) accessed via Lightweight Directory Access Protocol (LDAP).
- A Web Feature Service (WFS)-based communication service as a mediator between sender and receiver of so-called communication objects.
- A cloud service used to buffer communication objects, as a general data storage for the network, and as a platform to initialize and run OGC compliant web

services (WFS, Web Map Service (WMS) and Web Map Tile Service (WMTS)) on its stored data.

This lean infrastructure (combined with its communication approach presented in the next section) also keeps the participation requirements for third party systems low.

IV. COMMUNICATION

Three basic rules apply to communication within a ClusterWIS network: Data and (service) requests are always transferred by secure connections and encrypted by the public key of the recipient. Furthermore, recipients account for conformant data usage inside their domain. Finally, it has to be assumed that many communication partners and systems are regularly offline (e.g., when being in the forest with bad reception).

A. Communication Object and Encryption

The aforementioned communication objects are a means for the secure transfer of data and corresponding requests. As shown in Figure 2, a communication object consists of two parts: The non-encrypted transport information (top) and the encrypted secured message (bottom).

While not encrypted, the transport information is still secured by transport level security using HTTPS. It comprises information on the sender, the receivers, the utilized encryption (see below), and optional metadata used to flexibly add further information needed on transport level, e.g., to identify that a message is a response to another one.

The encrypted message comprises the intention in terms of a request, which can be, e.g., a service call, a service call response or a user-to-user message. It is complemented by parameters, e.g., for service calls (name of the service to be executed, surface under investigation, alphanumerical parameters), service call responses (a computation's result), or subject and body of a user-to-user message. Furthermore, embedded files, links to files on cloud services, or metadata describing files can be added.

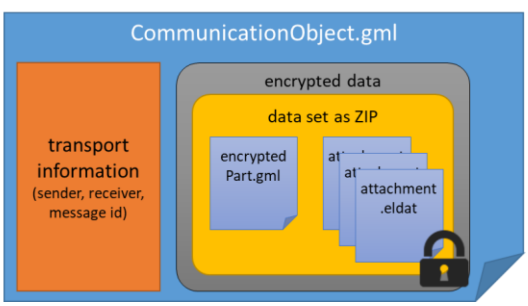


Figure 2. Implementation of the ClusterWIS communication object.

The communication object is implemented as follows (Figure 2): The to-be-secured message is stored as a GML file ("encryptedPart.gml"). The data set comprising this GML file together with the (optional) file attachments is stored in a ZIP file that is subsequently encrypted.

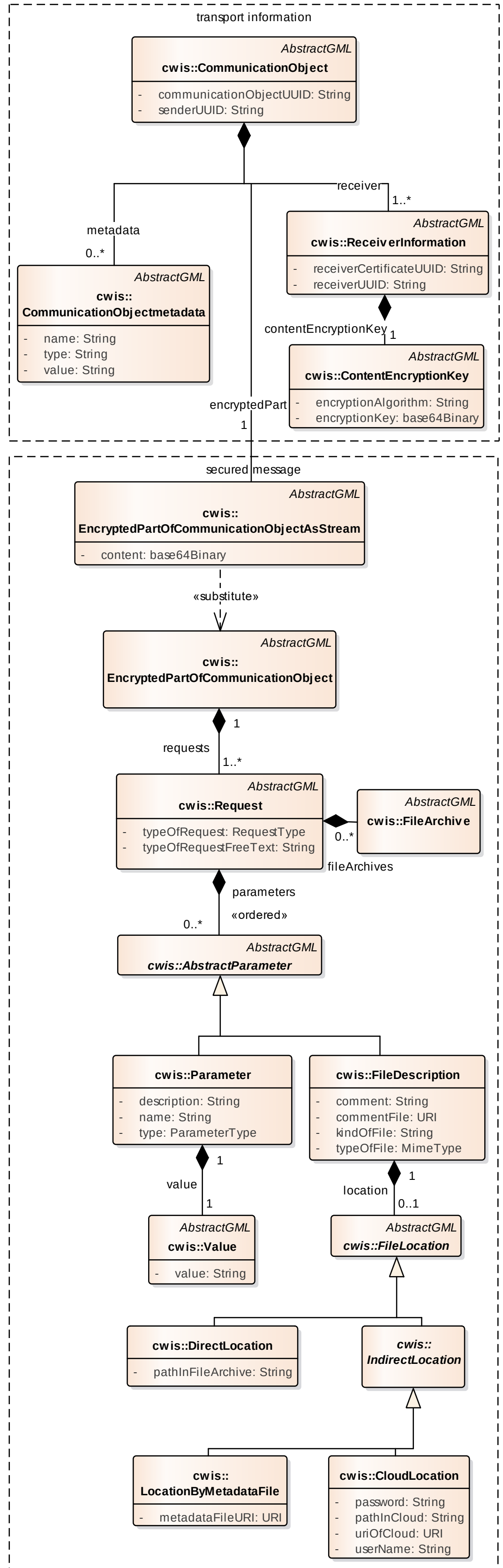


Figure 3. Structure of the ClusterWIS communication object.

The unencrypted transport information combined with the encrypted data is also stored as a GML file ("CommunicationObject.gml"). Thus, only the transport information remains readable.

Figure 4 illustrates the encryption of the communication object in more detail. First, the zipped data set is encrypted by an automatically generated symmetric key that is disposable and only used for this single data interchange. In turn, this key is encrypted by the receiver's public key and stored together with the user id of the receiver within the transport information.

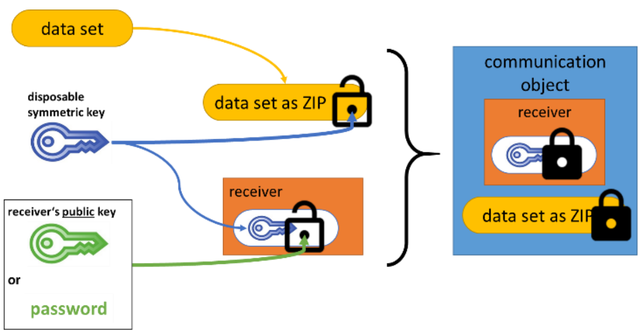


Figure 4. Encryption process of the ClusterWIS communication object.

This combination of encryption methods has three advantages:

- First of all, symmetric encryption is much more efficient on larger data sets.
- Secondly, the same data set can be encrypted for multiple receivers. For that purpose, the same disposable symmetric key is separately encrypted for each receiver of the communication object using the receiver's public key (Figure 5) and embedded into the transport information.
- At last, for the sake of keeping requirements low for participants in the ClusterWIS network, even users without a public/private key pair can participate. In this case, the disposable symmetric key is encrypted using a password agreed upon by the sender and the receiver(s).

For decrypting a message (Figure 5), the receiver uses his own private key only he knows (or the agreed upon password).

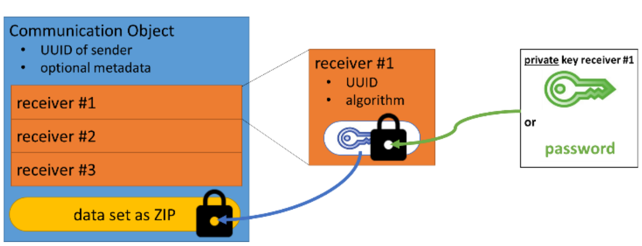


Figure 5. Decryption process of the ClusterWIS communication object.

This yields the disposable symmetric key needed to decrypt the ZIP archive containing the actual data set. Finally, the received data can be accessed.

B. Communication Service

The communication service operates the transfer of communication objects. Using HTTPS, a second layer of security is added to the encryption of the communication objects. This guarantees that neither unauthorized third parties nor the cloud service or even the communication service itself get access to the data.

The registry service provides information on the dispatch method for the communication objects, which may be different with regard to the receiving user (or node). Following dispatch methods are available:

- Notification by mail or smartphone push message including a download link to the communication object.
- Direct delivery using a WFS-like interface of the recipient.
- Actively pulling the list of new communication objects from the communication service.

The communication service provides a WFS interface that uses the unencrypted part of the communication object schema (Figure 3). Thus, a new communication object is sent to the communication service by using a WFS transaction (insert). For each communication object, the communication service creates a lightweight acknowledgement object (Figure 6) for message management. Here, any update to a communication object's state is logged (received, notification sent, communication object fetched …). Using these acknowledgement objects, the receiver can query a list of new messages (communication objects) from the communication service using a standard WFS query. Subsequently, this list can be used to fetch the actual communication objects themselves.

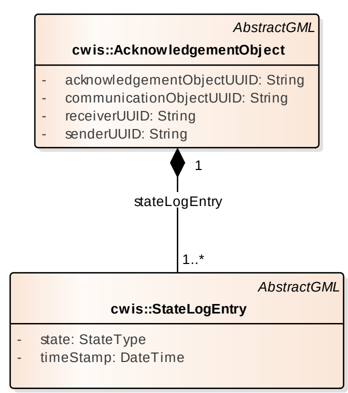


Figure 6. Acknowledgement objects provide an interface to fetchable communication objects.

A communication example is shown in Figure 1 (note that the disposable key is omitted in this sequence): A forest owner uses a browser to access the web application (Section V.B) and create a communication object with a request for forest inventory. It is encrypted (using the public key of the consultant) and sent to the communication service, which buffers it and sends a notification to the recipient (consultant). The latter starts its Forest Inventory application (Section

V.A.2), which asks the communication service for new communication objects that are subsequently fetched. Finally, the consultant decrypts the communication object with his private key and processes the message.

Note that all connections between nodes are additionally secured by client-side HTTPS, which is also used for authentication.

C. Open Platform Communications - Unified Architecture

The decentralized ClusterWIS approach is similar to those approaches subsumed as "Industry 4.0" in the manufacturing industry. Thus, it can be counted among current intentions relating to an adaption for the cluster forestry and wood dubbed "Forestry and Wood 4.0".

Furthermore, ClusterWIS communication not only takes place between actors but also from and to forest machinery. This motivates the integration of standard Industry 4.0 protocols into the network. As a well-established standard, Open Platform Communications – Unified Architecture (OPC UA) [27] is advisable for this purpose. Especially, as it provides a decentralized client server architecture without the need for central servers, it integrates well into the ClusterWIS PKI, it is an open and vendor-independent standard, it is robust, and it supports participants being temporarily offline.

Thus, to complement the aforementioned WFS-based approach, ClusterWIS nodes may also be equipped with an OPC UA client and server component allowing the exchange of communication objects.

V. Applications

An important part of the ClusterWIS approach are the user and scenario specific portals the actors can use to access the network. These comprise desktop, mobile and web applications.

A. Desktop and Mobile Applications

Desktop and mobile end-user applications provide online as well as offline access to ClusterWIS features. They can be used by actors like forest owners, service providers, or contractors to view, gather, modify, and exchange forestal data. In the context of the research project, applications are based on the Virtual Forest prototypes. They use the VEROSIM framework [28] that combines an integrated runtime database with subject-specific modules to create adapted applications for diverse scenarios.

Four different applications are being developed and refined to meet the requirements of the project's reference processes as described in Section VII:

1) Forest Information

The Forest Information application acts as an information portal to the data managed by ClusterWIS. Its primary functions are visualization, combination and analysis of geographic and business data, e.g., orthophotos, satellite imagery, LiDAR, cadaster, inventory, or regulatory data. This data may be available locally via files and databases or provided by OGC-compliant web services (WMS, WMTS, WFS) within the ClusterWIS network.

2) Forest Inventory

This application supports the forest inventory process. It allows a service provider to work with data made available by the commissioning forest owner and provides tools to record relevant stand attributes and single tree information. As this data is typically gathered on-site, the software also offers assistance for spatial localization during the process.

3) Forest Planning

The Forest Planning application provides a user-friendly and efficient interface to forest growth simulation. This comprises input parameterization as well as result analysis and visualization. The computationally intensive simulation itself is sourced out to a service (see Section VI.B).

4) Technical Production

This application supports the technical production process in its different phases, namely preparation of work assignments, assistance of forest workers and machine operators with instructions, and practical guidance as well as documentation of the harvesting operations and its results.

B. Web Applications

Web applications are ideally suited to provide a low-threshold access to the ClusterWIS network. They do not need client-side installation and can be used on both desktop and mobile devices alike. Capacity and performance scaling is easy and new features can be provided to users with no effort. Finally, web applications easily support operation in secure networks.

The browser-based GIS SGJ GeoHornet is one example of such a web application that is used in ClusterWIS. It has already successfully been employed in the Virtual Forest project as well as its commercial spin-offs. Various data sources like ForestGML databases or web services can be accessed and embedded. For example, registered forest owners can get an overview of their entire property. GeoHornet also provides methods to plot maps and enhance these plots with own graphical and textual annotations. It can create, send and receive communication objects, e.g., to send a request to another actor in the ClusterWIS network or to commission a service-based computation. GeoHornet can be customized for the user's demands.

VI. Specialized Services

Based on the backbone services of ClusterWIS (Sections III-IV), a large variety of specialized services for supporting particular business processes can arbitrarily be interconnected. Examples for such services are the processing of remote sensing data or the simulation of forest growth. As a single requirement, a specialized service has to comply with the ClusterWIS communication approach and its PKI.

Within a typical scenario, an application might call a service for data processing and store the results either locally or in a ClusterWIS cloud service. Subsequently, it might run two complementing simulation services based on this preprocessed data set. Finally, the application might use various evaluation services for evaluating the resulting scenario data.

A. Remote Sensing Data Processing

Often, the data necessary for a sustainable feedstock management can only be made available using remote sensing methods like tree species classification [9], stand attributes evaluation [10], or single tree delineation and attribution [11]. However, such methods usually need to access, process and store vast amounts of raw geo data, unfeasible, e.g., for mobile apps. Furthermore, existing methods need to be enhanced to easily incorporate stakeholders to refine the data with their expert knowledge (e.g., provide tree samples to optimize local tree species classification results). Thus, a goal of the ClusterWIS project is to make these methods available as services to allow the usage of suitable hardware on server side and to provide service interfaces for user provided calibration data.

B. Forest Growth Simulation

Forest growth simulators - beyond scenarios of stand development - provide further services that are closely connected to a simulator's core function. Such services are virtual tree generation based on stand structure attributes and computation of assortments using individual tree data. Hence, one relevant task within ClusterWIS is to extend existing data formats, such as ForestGML, to comply with the time-related data content that is specific to simulation models.

SILVA provides stand development as a result of rule-based management plans. That way, the simulator may provide scenarios that put emphasis on a specific subset of ecosystem services or that promote the development of specific stand structures and species mixtures. The seamless and manifold integration of SILVA [7] into the ClusterWIS infrastructure enables its coupling to any other service that might receive data from the simulator or provide essential basic data to it. That objective is particularly important against the background of ecosystem service provision. Ecosystem services are typically linked by mutual synergies and tradeoffs. Therefore, one relevant coupling scenario is the linkage between SILVA and vegetation distribution models. Such specialized land surface models [14] represent processes of vegetation growth, seed dissemination and disturbance. They may thus provide valuable results about the establishment of regeneration trees and individual young trees to forest growth simulators. Moreover, as vegetation models often use a simplified representation of main stand development, they might straightforwardly integrate individual tree data provided by the growth simulator.

C. Evaluation Services

While simulation services such as SILVA may provide built-in components for result evaluation, ClusterWIS may also complement such simulation services with dedicated evaluation services to provide them in any environment desired. Evaluation services may be readily implemented by forest and wood scientific staff within statistical environments such as R [29] that do not presuppose profound experience in software development. For example, R based evaluation services may simply be exposed by embedding them into ClusterWIS compliant service wrappers that call the R runtime with script name and parameters. As R provides packages for convenient XML parsing, a wrapper may straightforwardly pass ForestGML data to and from the script being called. Thus, an evaluation service may run on simulation results or survey data that has been generated on a remote system by services hosted on a different platform.

VII. Reference Processes

ClusterWIS not only provides an infrastructure, protocols and applications. It also specifies processes for a sustainable feedstock management realized on this foundation, which will be tested and demonstrated in actual forest stands. An important aspect of ClusterWIS is that these processes do no longer take place in a parallel and unrelated manner but start to interact with each other. A selection of practically relevant reference processes is considered within the project and briefly introduced below:

A. Forestal Data Provision

Sustainable natural resource management requires information and planning. For that purpose, up-to-date, highly qualitative, and detailed (geo) data is needed. Data is usually compiled of various data sources (ForestGML-structured data, third party spatial base data and business specific data). Currently, the comprehensive provision of such data to the cluster is an unresolved problem. Thus, this process describes the provision within the ClusterWIS network.

B. Forest Information

This process describes an actor's access to the provisioned forestal data of a specific area in the right time at the right place, comprising visualization, analysis, and editing.

C. Forest Inventory

Forest inventory is the acquisition and management of environmental data in forestry. Thus, the purpose of this process is to provide the cluster with always up-to-date, detailed and high-quality data. An important aspect in this context is to automatically and logically connect different data sources and, if applicable, different timestamps (for trend analysis) within the *n*D forest information system.

D. Planning and Consulting

The comprehensive data provided by the ClusterWIS network enables consultants to give forest owners efficient and goal-orientated advice on how to manage their forests. In particular, they can use simulation tools to demonstrate how different management alternatives result in different future outcomes.

E. Timber Trade

The ClusterWIS network opens new ways for getting in contact. By providing all relevant information to all actors involved in the process, a more efficient communication between sellers and buyers can be established. Thus, ClusterWIS provides the framework for a more efficient timber trade and contributes to a more efficient wood and biomass mobilization.

F. *Sustainable Harvesting*

Integrated into the aforementioned processes within the ClusterWIS network, the technical production process can access a vast number of relevant data. This allows for the planning of more sustainable harvesting measures. It comprises the (simulated) determination and visualization of wood assortments, harvesting costs, accessibility and harvesting routes, average skidding distances, as well as aspects of nature conservation. Besides planning, this process also comprises the execution of planned measures and their documentation, where the latter can again be used in downstream processes.

VIII. DEMONSTRATOR

In order to implement and test the developed concepts and to showcase them to potential users, a demonstrator has been created. It serves as a proof of concept and includes prototypical implementations of different applications, services and processes as described above.

The current demonstrator contains two demo scenarios focusing on different aspects of the aforementioned reference processes.

A. *Demo Scenario: Forest Inventory and Planning*

This scenario contains aspects of the reference processes “Forestal Data Provision”, “Forest Information”, “Forest Inventory” as well as “Planning and Consulting”. It addresses the private forest owner’s demand to easily get up-to-date stand attributes and data evaluations for his forest as a basis for further planning.

The forest owner uses an Android app (Figure 7) with a GIS user interface to connect to the ClusterWIS network.

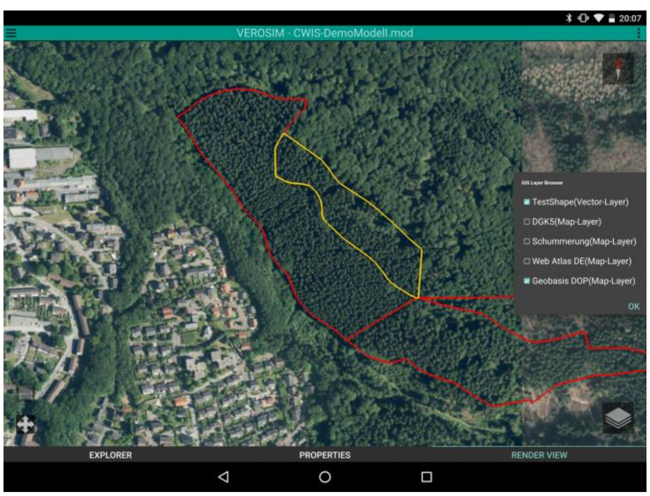
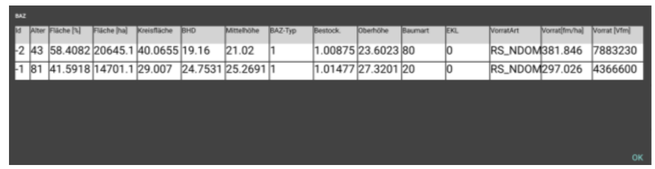


Figure 7. ClusterWIS Android app for the forest owner.

Various freely available WMS are integrated and provide geo data like orthophotos or LiDAR images. Using a remote service for remote sensing data processing (see Section VI.A), the user can retrieve automatically calculated forest inventory data for his or her forest areas just by selecting the desired areas and invoking the service by a simple push of a button (Figure 8). The service receives the work order packaged in an encrypted communicating object that also contains the surface to process on via the communication service. It uses remote sensing data to calculate stand attributes (tree species, area, age, stock volume, top height etc.) and creates a new communication object containing the encrypted results, which are sent back to the forest owner’s client app using the communication service, as well.


BAZ

Id	Alter	Fläche [%]	Fläche [ha]	Kreisfläche	BHD	Mittelhöhe	BAZ-Typ	Bestock.	Oberhöhe	Baumart	EKL	VorratArt	Vorrat[fm/ha]	Vorrat [Vfm]
-2	43	58.4082	20645.1	40.0655	19.16	21.02	1	1.00875	23.6023	80	0	RS_NDOM	381.846	7883230
-1	81	41.5918	14701.1	29.007	24.7531	25.2691	1	1.01477	27.3201	20	0	RS_NDOM	297.026	4366600

OK

Figure 8. Exemplary stand attributes result from ClusterWIS remote sensing data processing service in the Android app for the forest owner.

In addition, several R-based evaluation services (see Section VI.C) have been integrated into the demonstrator. Based on the previously generated stand attributes, they calculate values like groundwater recharge [30] or key indicators of biodiversity [31]. The results are visualized in the form of diagrams (Figure 9).

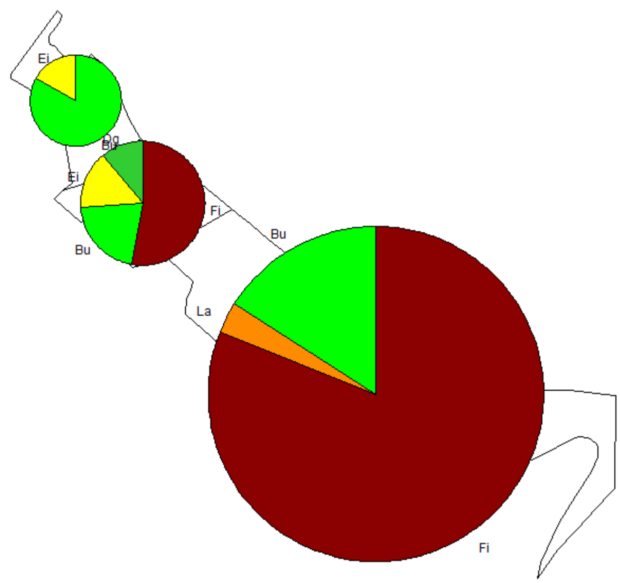


Figure 9. Stand inventory data aggregated to the forest owner specific resolution level (volume share per species and stand) by the ClusterWIS evaluation service and presented in the Android app for forest owners; tree species distinguished by color and abbreviation (Bu: European beech, Ei: oak, Dg: Douglas fir, Fi: spruce, La: larch).

The service is used the same way:

- The user selects surfaces,
- invokes the service call,
- an encrypted communication object containing both is sent to the service via the communication service,
- results are calculated, encrypted and sent back in a new communication object via the communication service, and

- the user's client fetches the new communication object and presents the results.

By using these two services alone, the forest owner already gets a considerable amount of information about his forest on demand and without the need for locally stored masses of geo data, for massive local computing power or for doing site surveys. This information serves as a basis for further planning of tending and felling measurements. The forest owner usually relies on other experts to get efficient and goal-oriented planning advice. To support this process, the mobile app gives access to a "yellow pages" feature, which is based on the registry service, where the user can search, e.g., for consultants registered in the ClusterWIS network and correspond with them directly via his app. In addition to a written request, other relevant data can be attached to the message that is forwarded to the recipient via the communication infrastructure described in Section IV. That way, forest consultants may offer support in forest planning based on the data within the secure communication object. Such planning, in turn, may be backed by scenarios from simulation services like SILVA (see Section VI.B).

B. Demo Scenario: Timber Trade

This scenario builds on the previous one and addresses the reference process "Timber Trade". Having planned or already conducted a felling, the forest owner wants to sell the harvested wood to a selling agent or directly to a saw mill.

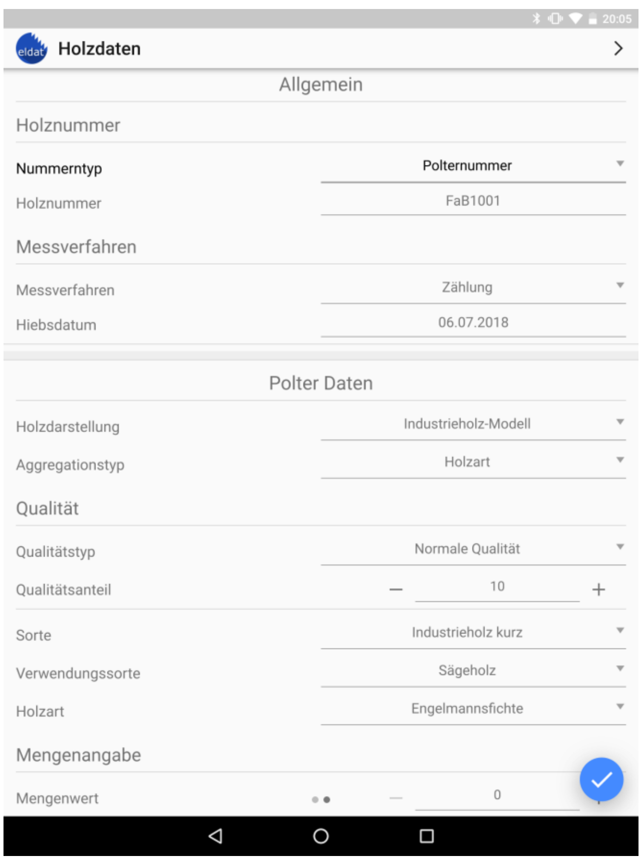


Figure 10. ClusterWIS Android app with a timber logistics user interface for creating ELDATsmart jobs.

For that purpose, he can use the Android app (Figure 10) to create the appropriate ELDATsmart-based timber logistics job for wood allocation. Again, the "yellow pages" feature integrated into the ClusterWIS network helps him find a registered selling agent or saw mill operator. Subsequently, he can send the generated wood allocation job to the chosen recipient using the ClusterWIS communication infrastructure.

The communication partner on the side of the selling agent or saw mill retrieves the message using his own client application, extracts the ELDATsmart file and can continue to use it in his usual workflow.

A similar user interface for timber logistics was also created for a prototype of a ClusterWIS desktop app (Figure 11). Here, the user can also derive ELDATsmart-based timber logistics files, e.g., for wood allocation, which is (in parts, where applicable) derived from inventory data and can subsequently be sent using a ClusterWIS communication user interface within the app.

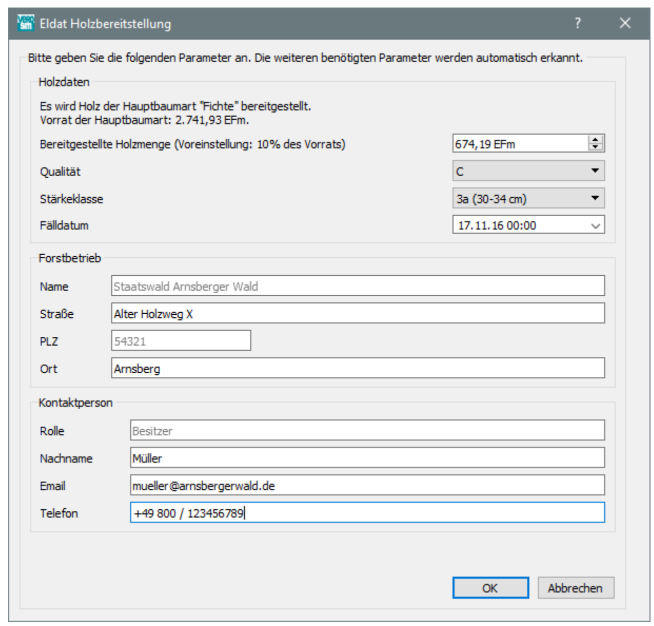


Figure 11. ClusterWIS desktop app with a timber logistics user interface for creating an ELDATsmart wood allocation job.

C. Achievements

The demo scenarios implemented in the current demonstrator showcase a variety of concepts and their practical application in real world scenarios. They demonstrate the communication between the cluster's actors, easy and inexpensive information retrieval and processing via user-specific applications and the integration of service providers into the network.

Furthermore, the demonstrator is a proof of concept for the technical aspects of ClusterWIS. For example, different types of nodes have been implemented and connected to a network:

- Desktop and mobile applications tailored to the needs of private forest owners.

- Automated services that calculate stand attributes and evaluations on demand based on remote sensing data.
- A user registry service providing lookup functionality using LDAP.
- A communication service transporting user-to-user and user-to-service messages.

The nodes communicate via HTTPS utilizing the ClusterWIS PKI and communication objects as described above. Client applications and services implement an interface to ForestGML and are able to serialize and deserialize data like surface geometries, stand attributes and evaluation results. In addition, the evaluation service based on SILVA demonstrates the successful integration of existing software into the ClusterWIS network.

D. Presentation and Feedback

The ClusterWIS project and its current demonstrator were successfully presented at the INTERFORST 2018 [32], an international leading trade fair for forestry and forest technology in Munich, Germany. Private forest owners, freelance forestal experts and service companies showed a particular interest. In general, most visitors expressed the willingness to participate in a network like ClusterWIS.

Especially small forest owners see a great advantage in the ability to get forest inventory data in an inexpensive way as such data is usually not easily available without a traditional forest inventory measurement. There is also a demand for lightweight apps and web portals as costs and complexity of traditional desktop software are not feasible for many forest owners. Easy to use and intuitive user interfaces are a must for such apps and portals.

Another aspect favored by some forest owners was the straightforward communication with other actors, which improve their independence and avoids fees for intermediation by third parties.

While the consistent use of end-to-end-encryption was well received, some visitors expressed security concerns regarding the public accessibility of the network. Some kind of “supervisory body” to review registered users was suggested. Some forest owners also fear that the structures of ClusterWIS might promote the dictate of pricing by buyers of timber like saw mills. These concerns deserve particular attention and will be considered in the further course of the ClusterWIS system.

IX. Conclusion

The cluster forestry and wood is an important economic sector. Yet, its major challenges (structural complexity and heterogeneity, huge number of stakeholders, and decentralized processes) are insufficiently addressed in current IT solutions. The ClusterWIS approach can resolve these problems by providing a decentralized, secure, and lean infrastructure for communication and data management. Based on this infrastructure, services and applications are orchestrated to realize novel, interconnected, and sustainable processes for feedstock management among the cluster’s actors.

As presented in the paper at hand, in its current phase, most ClusterWIS services and apps are implemented and integrated into a comprehensive demonstrator. The feedback to this demonstrator already shows the high interest of different actors (forest owners, service providers …) in ClusterWIS-based solutions.

Next steps within the project comprise the integration of a payment infrastructure to allow service providers to offer payed services and the implementation of a tree species classification service based on user-provided local samples. Subsequently, the demonstrator will be complemented by further aspects of the reference processes.

Acknowledgment

The research project ClusterWIS is co-financed by the European Union and the German federal state of North Rhine-Westphalia: European Union - Investing in our Future - European Regional Development Fund (EFRE-0800036, EFRE-0800037, EFRE-0800038, EFRE-0800088).

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