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Building Seamless Network Infrastructure for Scalable Service Integration in Smart Enterprises

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Abstract

Building seamless network infrastructure with resilient QoS provisioning capabilities is important for integrating multiple virtualization technologies and scalable multiple service level agreement (SLA)-based services in an enterprise supporting large organizations and crowds. In this paper, a cloud network infrastructure for SLA-based networking as a service (NaaS) is introduced, which can evolve with SDN/NFV-based cloud networking innovations . Moreover, an intelligent agent-based reliable service provisioning framework is proposed that helps networking and cloud service integrating in a seamless manner in enterprises by investigating the cloud networking technologies and their interoperability challenges. Smart Enterprises are being formed and expanded by numerous organizations near and far owing to the fast advancement of information and communication technologies (ICTs). Their business process entails integration with numerous services of diverse service providers. Cloud service provisioning needs faster on-demand integration of possible service providers and their services in an enterprise. In such an enterprise with thousands of service providers, scalability, performance reliability, security, customer driven SLA assurance innovations and QoS monitoring are mainly important for meeting future service provisioning needs . Resilient QoS provisioning capabilities are critically important for large NeTs supporting enterprise-wide and city-wise resilient communications. Key innovations include new architectures for Wide Area, Access and Metro coalescence, SDN/NFV-based cloud networking innovations, cloud resource-rich network infrastructures and new QoS provisioning algorithms. Huge numbers of large Carrier NeTs are being massively deployed with numerous access technologies in many places, which is critical for the sustainable expansion and early realization of Smart Cities. Wi-Fi hotspots, Mobile Cellular communications and Optical Fiber access are a few add-on examples.
Keywords : Collaboration, communication, connectivity, social networks, interoperability, integration, web services.Network Infrastructure,Scalability,Service Integration,Smart Enterprises,Seamless Connectivity,Software-Defined Networking (SDN),Network Virtualization,Load Balancing,Quality of Service (QoS),Edge Computing.

1. Introduction

Rapid configuration and deployment of new services is a necessary step for meeting innovative business requirements. There are only limited out-of-the-box solutions for building a seamless network infrastructure in service-oriented environments due to the complexity of service interoperability in widely distributed networks and massive service resources. Federated service-oriented architectures turn service resources into service domains, forming a distributed service network for scalable service integration. Interoperability is a significant challenge in federated service-oriented environments due to the use of heterogeneous service representations, protocols, and communication paradigms by different service domains. A hybrid ontology mapping framework is proposed that combines both schema mapping and instance matching approaches. Detection of service representation discrepancies can be dealt with in a lightweight yet effective way by developing a novel service ontology alignment approach in a modularized manner. On the basis of schema mapping, another service ontology alignment approach conducts instance matching and provides matching traceability. In addition, a composite matching model is then developed, which can be used as a bridge to map from the domain ontology to the operational ontology. The state-of-the-art developments in business process management have shown that federated business process composition approaches accommodate the growing demand for flexibility in a dynamic environment .

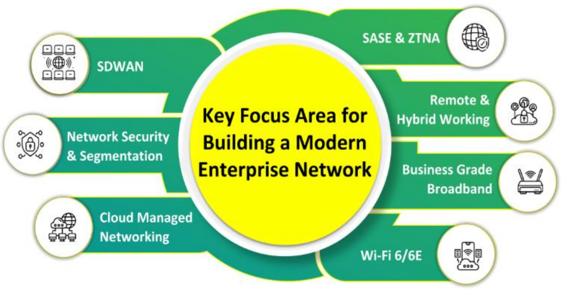

Fig 1: Enterprise Network Services

However, to support these approaches, a proper service-oriented architecture for a control, banking, or logistics enterprise is needed, where hosted services and their descriptions are maintained in an automated and standard-compliant way. Although multiple research approaches in the two areas propose a high-level solution to enhance the current situation, there is still a lack of a detailed system design specifying the seamless virtual service integration in a federated service network environment. More recent work has focused on data-oriented business service discovery, which can be applied for improvement in business application integration technology at the level of data-oriented functionality as well.

1.1. Background and significance

The development of smart services in the new generation of 'smart enterprises' (SE) promotes scalability in service creation and delivery over a decentralized and dynamic Internet as a service 'ecosystem'. Different types of service-seismic integration for the delivery of market-oriented smart services demand novel integration technologies that cover various service integration requirements and scenarios. In this context, users can not only easily discover and consume interoperable services regardless of their execution locations and owners, but also integrate and enrich cloud services. The intelligent integration of services can hence offer a powerful competitive advantage to virtually any business. Despite significant efforts to meet the foreseeable demand for new types of composite smart services, no comprehensive service integration solution is available at present. Different pieces of the aforementioned new integration technologies are at various stages of development and lack seamless interoperability between them. New service-oriented computing (SOC) and cloud computing (CC) technologies are increasingly employed for the modeling, composition, and hosting of services from various domains. Numerous cataloged open services are nowadays delivered and consumed over the Internet by various user types and via various user devices.

Equ 1: Network Capacity Model

$$C = \sum_{i=1}^{N} B_i \cdot U_i$$

- C = Total network capacity (bps)
- N = Number of network segments or devices
- B_i = Bandwidth of segment/device i
- U_i = Utilization factor (0 to 1) of segment/device i

2. Understanding Smart Enterprises

The emergence of Smart Enterprise is a result of the continuous development and evolution of IS-based enterprise solutions. A Smart Enterprise is a new business model that leverages existing investments in IS-based enterprise solutions as well as the power of the internet and emerging trends, such as Cloud and SoA, to create a new collaborative enterprise framework, promote the seamless sharing and reuse of heterogeneous enterprise data and services, and facilitate multi-enterprise business collaboration across the extended enterprise. A framework for the implementation and deployment of Smart Enterprise is outlined, which consists of a Business Collaboration Model, Technology Architecture, Composite Service Orchestration Model, and Multi-enterprise Web Services. Based on this framework, a roadmap with key technical areas is proposed to facilitate the implementation of a Smart Enterprise. The implications of Smart Enterprise for future research are examined.

Globalisation has resulted in intense market competition and an ever-changing and increasingly complex business environment. Enterprises can no longer survive in isolation and must collaborate with other enterprises to deliver value to customers. However, the traditional view of an enterprise as a set of functional areas has changed. Recently, driven by collaborative competitive motivations, firms must look at the competition from an inter-enterprise perspective . In this new competitive environment, business collaboration across the extended enterprise must change from traditional, cost-ineffective one-to-one collaborations to a new community-based, real-time, and knowledge-facilitated paradigm. To facilitate the development of a new service-oriented community-based business model, this research investigates the evolution of collaboration and how contemporary IS-based collaborative enterprise solutions could facilitate the new collaborative business model. The emergence of a Smart Enterprise is discussed, which leverages existing investments in IS-based enterprise solutions as well as the power of the internet and emerging trends, such as Cloud and SoA, to create a new collaborative enterprise framework.

This framework promotes the seamless sharing and reuse of heterogeneous enterprise data and services, facilitates multi-enterprise business collaboration across the extended enterprise, and encourages new business opportunities and service innovation. A framework for Smart Enterprise is developed to answer the questions of what is Smart Enterprise and how to implement a Smart Enterprise. This framework comprises a new collaborative business model, a technology architecture, a composite service orchestration model, and a multi-enterprise web service infrastructure. A roadmap with the key technical areas of smart service-based collaborative enterprise solutions is proposed, including agent-based

SOURCES, multi-resolution and multi-temporal service integration and collaborative information management, and business process semantics and dynamic service collaboration.

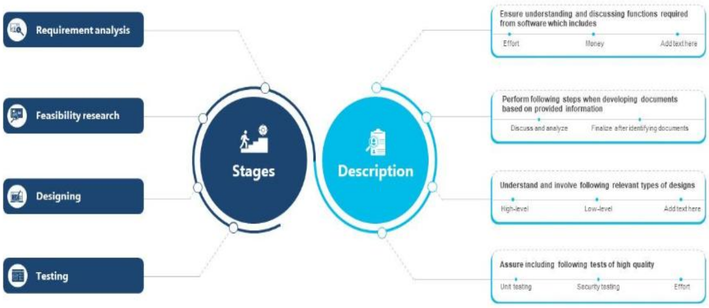

Fig 2:Smart Enterprise Systems

2.1. Definition and Characteristics

Networked enterprise information systems (EIS) incorporate several types of systems that communicate with one another over a network to exchange data and information, constituting a heterogeneous environment. Actual trends of collaboration, joining efforts and sharing resources among various enterprises arise because no single enterprise possesses all the necessary resources for pursuing and achieving a common objective. EIS interoperability, i.e., the ability of interacting EIS to exchange data and information, is therefore crucial for enabling this collaboration. Actually, it is a highly demanding and critical task to integrate legacy and heterogeneous information systems in the context of the networked EIS. The EIS interoperability problem can be addressed from several perspectives, focusing on data, processes, knowledge, software, services, and so on. Information and communication technology innovations that guarantee both low-cost and high-bandwidth data transfer have brought a spectrum of new opportunities. One result is the emergence of factory and enterprise networking and the integration of enterprise systems such as Enterprise Resource Planning or Product Lifecycle Management systems with that. With the expanding desire on the international and global levels for business networking with a wider spectrum and diversity of trading partners and service vendors, concerns about the technological mediation and delivery of messages between these disparate systems have arisen. These interoperable environments are often called networked enterprise information systems or EIS. Due to the inherent complexity of the operational environment and the relative complexity of the integrated toolboxes, achieving the expected functional reductions cannot be taken for granted.

Networked EIS must be tailored to the specific requirements of the given application domain while keeping generic and flexible enough to be able to cater for future evolution. Modularity, abstracted complexity hiding, and easily updated parts are indispensable properties. Hopefully, the resulting systems indeed lead to functional reductions, because factory and enterprise data processing systems normally tend to increase in number, complexity and untraceable — or even unexplainable — ways. Evolutive interoperability is a facet of EIS interoperability that focuses on the challenges arising when integrating legacy systems and on system design and architecture proposals. In evolving and dynamic environments, the requirements, conditions of operation, and specifications of each EIS change and evolve, which may introduce incompatibilities and the need to enhance the EIS with new resources or capabilities. They include the necessity of trading heterogeneous and legacy systems, the evolution of systems over their lifetimes, and the addition and removal of systems. Traditional EIS interoperability or integration solutions are often inflexible and rigid, and difficult to adapt to the requirements of rapidly changing environments.

2.2. Importance of Network Infrastructure

In smart enterprises, all the information equipment must be interconnected to implement seamless business and services integration. For this purpose, a network infrastructure is essential for smart enterprises. In the early stage of the Internet, proprietary systems and protocols prevailed. With the continuous acceptance of interoperability, standardization has been progressively emphasized. Plug-and-play network devices based on standard protocols are now prevalent in communication systems, including smart enterprises. However, there are still serious inconveniences, which turn out to be the major challenges for the future smart enterprises. Such difficulties and barriers of integration must be considered in close relation to an overall solution for smart enterprises as a large and complex ecosystem.

Smart services integration requires multiple heterogeneous service resources (computing, storage, communication, etc.) to be interconnected in a seamless and scalable fashion. For this purpose, a seamless standard communication protocol for information interconnection is an essential prerequisite, which includes a semantic information representation and its conversion to and from a binary format. On the other hand, since the availability of information communication devices has increased rapidly and is expected to continue in the foreseeable future, it is important to reduce the complicated and burdensome procedures for the maintenance and management of communication devices. In standard communication

networks, communication devices can be interconnected through the IP addresses. However, there are still serious inconveniences for the maintenance and management of a large and complex network infrastructure. Thus, there is a need for a non-redundant, non-dedicated method/circuit for information communication in a smart enterprise. Due to the intrinsic difficulty of integration, SDN may rather hamper existing traditional fixed-function networking devices exhibiting the same/standard protocols or vendor-specific devices, which fail to support information transporting and processing services for the purpose of seamless service integration.
The network infrastructure for smart enterprises is categorized into two levels: communication networks and switching infrastructures. The cloud computing paradigm provides both of them as programmable, automated, elastic services, i.e., network as a service (NaaS). However, to build a NaaS, there are serious and non-trivial considerations associated with information interconnection and device management. In addition, in the case of service change or expansion, there will always be a new communication device/protocol to support the service. Therefore, a seamless, efficient, and easy-to-use network infrastructure is essential for scalable service integration of smart enterprises.

3. Current Trends in Network Infrastructure

In modern times, one of the largest challenges faced by enterprises and firms is that of seamlessly integrating multiple services together. In most firms, there are multiple disparate systems running side by side. For example, in most smart factories, there exist different ERP systems such as SAP by the manufacturing unit of the firm, different inventory management systems by logistics, and different analytics systems run by data engineers. Each of these systems encompasses different hardware architectures, unique operating systems, multiple protocols, and often proprietary broadcast/message standards. Furthermore, they often run decades-old legacy code that firms are reluctant to discard. Attempting to force one of these silos to speak to the other may take years and tremendous resources, and ultimately may still fail. Even when successful, firms fear the loss of their intellectual property contained in these proprietary standards. Software mines and firms on the cloud have sprung into existence and may safely transfer any sort of data over the clouds. However, they all have the same drawbacks. Any industrial espionage against these firms may lead to disastrous leakages of critical, sensitive data. Additionally, the sheer latency involved in even inter-process communication located on the same server farm makes these solutions unviable for real-time applications. For example, a million-pixel camera broadcasting 1000 frames/second requires at least 240 Mbit/s raw non-compressed input.
Network data transfer rates have increased exponentially compared to processing capability. The dawn of the information age was characterized by the move from mainframe computers to terminal networks. Baseband data transfer rates of 2.4 Kbit/s over twisted pairs, both serial and parallel cables with rates of 500 Kbit/s, were made possible through the clever multiplexing of heavily synchronized sending and receiving clocks. Additionally, coherence conditions in optical linkages allow data transfer rates of many hundred Gbit/s to be realized. Satellites of the biggest mobile phone carriers can transfer terabit rates to the ground staff. Each of the biggest data centers has 200 Mbit/s bandwidth connections to the backbone. However, this throughput still belies processing, rendering, and storing capabilities. Individual memories operate at rates of many hundred Gbyte/s levels, while consumer solid-state storage disks return data at rates of 600 Mbyte/s over the SATA protocol. Data transferred by the desktop may take hours to write on the disks. Similarly, in the real-time scenario, it takes even longer to read it back and process the data. While analysis takes hours, results may take days to return back to the screens. Currently available cloud options may process disk input at rates for micro-batches of hundreds of seconds and broadcast the results back to local desktops and displays at Gbit/s. Even this throughput is found to be insufficient for sophisticated reporting and running control on complex production machinery.

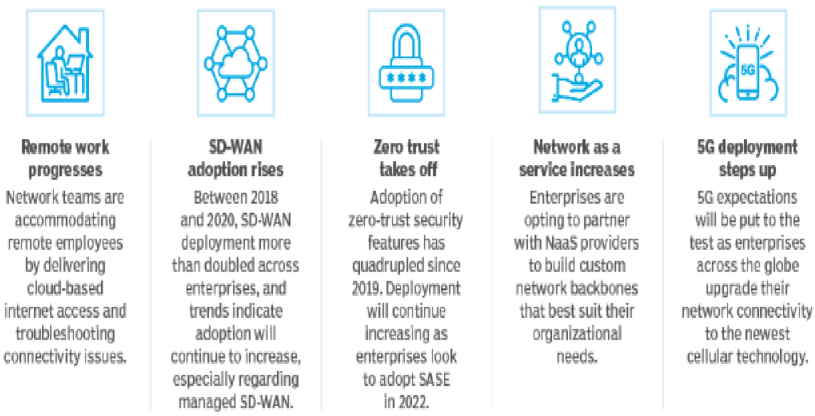

Fig 3: Trends in enterprise networking

3.1. Cloud Computing

Cloud computing is one of the most significant developments in IT today and is projected to transform the way many organizations use IT. Cloud service providers offer a variety of advancements and options to enable enterprises to leverage cloud computing. Organizations outside the SME segment or with limited exposure to cloud computing are actively exploring this option. The cloud is a major technology that will change the shape of business in the coming years and it is rampant today and evolving rapidly today. Cloud computing is the latest evolution of the Software as a Service (SaaS) model. The new generation of cloud computing is currently integrating advanced technologies for access control, security, and integrity. Cloud computing is the newest buzzword in the computer world today. It refers to the delivery of computing as a service rather than as a product on demand. This delivery model enables access to a shared pool of configurable resources over the internet. The resources include servers, storage, applications, and services that can be rapidly provisioned and released with minimal management effort. On the other hand, cloud computing is a globally connected architecture ranging from the user end to the server end in the data center, hence the risk assessment of cloud computing is more difficult than other technologies. Cloud computing has gained a wide area of attention in recent years due to various reasons discussed briefly as follows: low-cost, reduced IT management overhead, and easy access to scalable infrastructure. While many are drawn to the cost-savings potential of the cloud, there are also other strategic benefits to be derived. By using cloud computing resources, organizations can focus on their core competencies while off-loading the heavy lifting involved in the internal operation of IT infrastructure. Due to the cloud's recent emergence, there is much industry-wide experimentation along with practical usage patterns
.

3.2. Edge Computing

As a new paradigm in IT and communication systems, Edge Computing has emerged and been on the rise, owing to the advancement in terms of both hardware (e.g., inexpensive microprocessors/GPUs, sensors, and energy supply) and software (e.g., algorithms and services). It enables rich applications to run on powerful computing devices next to, or at the edge of, the mobile device that runs the client application, for example, smartphones or IoT devices while foregoing far-away cloud computing centers. Aiming at the latter and better resource and latency (or delay) performance, Edge Computing can be deployed in a wider range of locations at the Internet edge, including but not limited to base stations, modem routers, cellular switches, and Wifi routers. Recent years have witnessed the burst of edge-related research and industrial initiatives. Proposed by Carnegie Mellon University, Cloudlet is a specific solution to Edge Computing. Different from Cloud Computing, which consists of remote servers located at a cloud data center, Cloudlet is a trusted and well-connected computer or cluster of computers available for Mobile Computing. It is only designed for desktop and laptop users and thus much less helpful for mobile devices that are more constrained in terms of battery and computing resources.

Edge cloud systems (or Cloudlet systems) generally include two types of entities: front-end mobile devices that issue requests for services, and back-end edge devices that provide services over reliable TCP/IP (Transmission Control Protocol/Internet Protocol) networks. Typically, mobile devices are resource-constrained (e.g., by battery life, CPU/GPU capability, etc.) and some services like Augmented Reality (AR) are logging-intensive (e.g., complex computations and large amounts of data transfers). The underlying Cloud Computing has server and network resources that are complementary to mobile devices. However, Cloud Computing systems/solutions cannot be accessed/reached quickly due to the large latency, especially during handoffs. As opposed to remote machines, Cloudlet systems are designed to be trusted and located at the Internet edge, where service response time can be reduced dramatically.

Equ 2: Latency Model

$$L = \sum_{i=1}^{M} (d_i / v_i + t_i)$$

- L = Total end-to-end latency
- M = Number of hops or segments in a service path
- d_i = Distance of segment i (meters)
- v_i = Signal propagation speed in segment i (m/s)
- t_i = Processing or queuing delay at segment i (seconds)

4. Challenges in Service Integration

Smart enterprises rely on a rapidly growing number of services to optimize their processes. As more complex services emerge, they must be readily integrated into existing applications. Building a seamless network infrastructure for scalable service integration is a key challenge in this realm. Legacy implementations often address specific needs but lack flexibility to adapt to new needs, environments, and integration strategies. Services are often considered as black boxes, and behavioral integration is only possible through some externally defined hooks. In the case of tightly coupled integrations, interfaces of the services may start being modified to homogeneously sharing more and more common code.

Over time, all service behavior remains external and modifications do not require changes to the service internals, as they go from monolithic implementations to a composition of loosely coupled blocks. Integration strategies to manage an ever-growing number of available services have to be controlled, which may still involve changing some of the services.
With the proliferation of service-oriented computing and the development of formal specifications for services integration, numerous approaches for combining services have emerged. However, most of these approaches disregard certain aspects, making the construction of automated tools difficult. An automated combining technique cannot simply be constructed from existing techniques, as they either work on abstract representations that do not reveal any structure or are inapplicable to the context of service-oriented systems. Starting from challenges observed in simpler systems, an approach to recreating or reusing existing alliances of services in a potentially perforated DSO has been proposed.
Dynamic integration of SOA-based services as the emergence of new services or the calibration of existing ones. Efficient composing of SOA-based services against user pre-compositional preferences and restrictions, leading to the design of the new architecture of services. Interfaces provided by available services and platforms should be considered, and services that do not comply with these interfaces should be adjusted and modified. Even if the services to be composed are compliant with the required interfaces, it should be ensured that these services composition law and behavioral and functional compatibility must be documented. Provided services often do not comply with these specifications and have to be adapted or transformed before integration.

Fig 4: Service Cloud Challenges

4.1. Interoperability Issues

Seamless interoperability is essential for smart enterprises that aim to leverage collaborative networks for innovative modelling, process reengineering, knowledge management, and capacity planning. However, interoperability issues among legacy and new systems as well as subsystems have hampered swift seamless integration. While there are isolated case studies involving efforts to integrate parts of a new and legacy network, there is little analytical knowledge or exemplary case studies on seamless interoperability. An enterprise's strategy may not be aware of the challenges that the existing business model, business processes, and legacy information/communication systems will pose for seamless interoperability. Due to continuous change, the methods and models quickly become outdated or untrustworthy. It is difficult to keep track of the business processes implemented in the information systems. This leads to non-alignment between the business model and processes deployed. As the complexity and dynamism happen in the system's environment, the active elements of the enterprise task model can change rapidly. This lack of rapid adaptability can hinder the enterprise's performance. In this regard, it is essential to adopt a formal and systematic methodology for identifying and representing the interoperability requirements, issues, and components. The analytically structured knowledge can then guide the development of an architecture for seamless integration so that new, legacy systems, and relevant protocols can communicate, share, and cooperate effectively, efficiently, and securely in a networked collaborative enterprise. Networks of reusable service-oriented architecture and relevant protocols are new possibilities for 'plug and play' connectivity among a composition of systems. Given the autonomous ownership of systems, the current AAS-based basic standard will allow the interaction of subsystems. There are no existing efforts focusing on integration among legacy systems and/or space-systems which employ heterogeneous underlying structures. There are few academic studies on seamless interoperability.

4.2. Scalability Concerns

Network infrastructure is critical to enable connectivity in automated production lines. However, a distributed enterprise network is not only needed for machine-to-machine communication, but it also poses a challenge for scaling service

integration without high bandwidth demand. Building the infrastructure is hardly feasible since there are digital islands in various cloud services, outsourced cloud storage, and on-premises services. Enterprise technologies are vertically integrated and lead to vendor lock-in. Scanning for new nodes in a large and seamlessly integrated network is still applicable in a local area network, but service discovery is a challenge in a distributed network.
Automated service integration is proposed to meet these challenges. The building blocks of the new infrastructure are multiple cloud services, local nodes, and a bridge on-premise. Cloud services are IoT cloud services free from vendor lock-in. Local nodes are low-cost, small footprint computers with sensors or actuators. The bridge includes a traditional enterprise monitoring node with a costlier controller. All service integration and re-designs are done on local nodes. Internet-based cloud services or scanned automated local services are of no concern. Only edge nodes are scanned, minimizing bandwidth utilization and network hazards. A digital twin of the network is scanned in specified order at startup, and subsequently, during operation, service redesign could be possible without any impact on robustness and performance. Service integration of industrial IoT nodes was exemplified in a real factory run by simulated system states. Use case requirement specifications are discussed, enabling scalable and seamless integration of service modules in small low-cost platforms with horizontal scalability. Edge nodes are mostly low-cost external IoT cloud services, which are simple but can severely affect on-premise systems since big data transfer takes time. The proposed infrastructure is extensible to work with more services and nodes. Handling a flood of new nodes is an issue. Performance would worsen as nodes are added in a large framework, however, service integration remains an unnoticed background task for operators or automation personnel.

5. Designing a Seamless Network Infrastructure

Designing seamless network infrastructure to integrate systems across cloud-exclusive services specialist locations and easy access to remote data will enable highly-scalable and flexible service integration in smart enterprises. For flexibility and scalability reasons, it is important to avoid site specifics and limit provisioning to a national scale. Conflicting with these aims ad-hoc decided, site specifics, which may eliminate the whole advantages of cloud inclusivity and remote access options, are explicitly included in new infrastructure designs, hampering the aforementioned goals.
A systematic approach to seamless enterprise architectures guiding, which contributes to gradual transformation to a high-performance smart enterprise relieving management from time demanding and error prone ad-hoc manual decisions and control will be explored. To eliminate site specifics, network infrastructure must be designed anew or substantially redesigned. Two design criteria for a seamless network infrastructure will be presented which aim to provide the same services as before transitioning, as well as envisaged requirements. In addition, a design methodology to meet these criteria enabling satisfaction of operational site specifics inherent in the legacy design will be developed. This way emergence of site specifics and provision of unallowable services are avoided, thus enabling a much more efficient redesign of legacy infrastructure.
While many design methodologies for communication networks exist, up to now none addressing these complex problems has been published. Standardised mechanisms and protocols will be used to ensure simultaneous availability of both old and new infrastructure to facilitate gradual transition and a unified approach across different functional areas relying on the communication infrastructure. But for ensuring a coherent and smooth gradual transition a more unified modelling approach addressing high level enterprise views as well as low level implementation details is required, which is lacking as well. Therefore, an appropriate framework based on the Model Driven Architecture (MDA) approach to modelling and design using transformation levels will be presented.

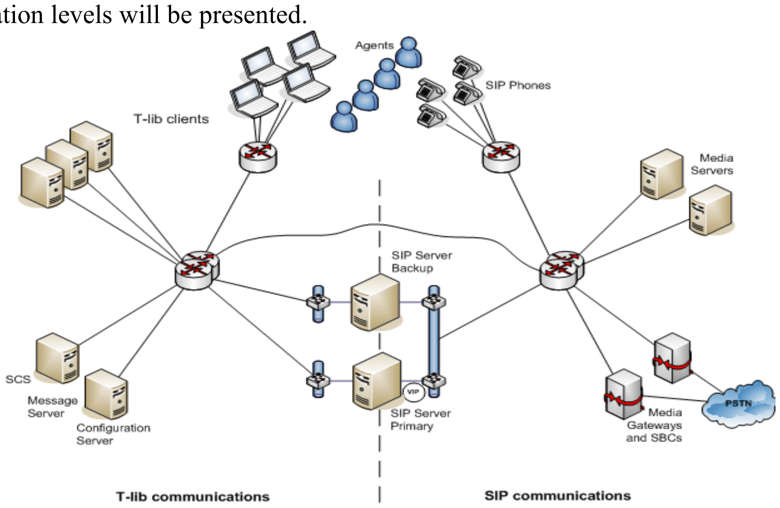

Fig 5: Network Design Considerations

5.1. Architectural Framework

The architectural framework is composed of: (1) a communication language and domain ontology called ECL (Ecosystem Communication Language) to allow a uniform and format for the requests and responses of the services colluding in the ecosystem; (2) a management language called EML (Ecosystem Management Language) that consists of high-level commands expressing a limited number of administrative actions to perform on the inner surfaces of the ecosystem; (3) an Ecosystem Integration Unit (EIU) that copes with the binding and unbinding of services composing the ecosystem, taking into account the possible uninstantiability of some of their service parameters; (4) an Ecosystem WMI Scripting Unit (EWSU) that scans the ecosystem's composition and self-adapts itself and its services to the requirements and needs all along with the period of time but also in case of sudden events. This unit is responsible for resource allocation and deallocation; (5) an Ecosystem Security Unit (ESU) responsible for the good operating environment of working services and ultra-tight protection of the ecosystem as a whole against malevolent network attacks . Relying on these components, the EAA framework allows re-building/deploying a sustainable ecosystem-oriented architecture defined upfront that satisfies a high-level application domain model and evolves afterwards to accommodate new/modified processes while sustaining its QoS and ownership constraints. At runtime, EEA allows continuously self-monitoring the running ecosystem-oriented architecture and autonomously triggering adaptation actions when it deviates from its design. These resulting changes augur actions on the architecture that change its on-going configuration, communication, and/or operating units instantiations and degree of integration, and translates them into a set of re-deployments of ELF-based operating environment descriptions.

5.2. Key Components

A smart enterprise provides domain-specific services that are expected to seamlessly interoperate with services from other enterprises in a large-scale, on-demand, flexible manner, and at a lower cost. Network and service providers are expected to offer service integration infrastructure supporting service composition and orchestrating applications composed of services from multiple providers without putting burden on end-users. To this end, a peer-based service integration infrastructure which utilizes edge computing and interoperates with centralized infrastructure is expected. Strict enforcement of service constraints by this peer-based infrastructure helps to ensure safety, reliability, and quality-of-service in executing composite applications using services from diverse providers . An autonomous and self-managing approach is needed to achieve this vision.

A viewpoint process model is proposed to develop a software architecture which enables independent implementations of the main functional components of the infrastructure. The infrastructure will be prototyped in the ongoing research effort. Peer-based service discovery is expected to leverage service ontologies along with service descriptions to efficiently locate appropriate services. Cyber-physical enterprises already have services to recognize, monitor, and understand the physical world. The service integration infrastructure must transparently integrate these services in federation with other services using the shared world model. Reaching target awareness and consistency within latency bounds is expected to be addressed by an ontology-based approach. A service composition model enabling automated service selection while considering heterogeneous service functionalities and constraints is expected.

Equ 3: Scalability Function

$$S(n) = S_0 \cdot (1 + \alpha \cdot \log(n))$$

- $S(n)$ = System performance or throughput
- S_0 = Baseline performance with 1 service
- α = Scalability coefficient ($\alpha > 0$)

6. Conclusion

The Enterprise's competitive advantage might be based on its operational capacity to cater to its current economic environment's needs: dealing with variability. Variability among the clients' requirements, end-customers final production inventory, and even variability with internal changes, all of those can be judged as firm exogenous volatility. A grubby operational setting can be sought providing latter variability with responsiveness, stability, complexity, and cost-competitiveness. Following that, a modulable reconfigurable network factory providing operations support to many similar production processes competing market numbers. Firing reconfigurable devices while on the process from one step to another due to emergency defects. And to avoid process collapse while resulting in too many idle devices, a clever random event firing time setting is resorted. As a result, a nonlinear factory productivity response due to variability lets hub-device firing or defect increases carryoff the opposite area development or decommissioning speed.

Some choices are made to meet all desires. Four lower-level elements for information use, internal as well as supply chain, are furnished. Facilities impact because global optimal devices must be assigned to production networks to still obtain global optimal. The low-level variabilities are traded-off by three options modelled with similar detail. All latter four sum up a straightforward ARX model. This topic should also incorporate information as is done in network scheduling co-development contexts. On top of this, continuous time-conditioned input models are introduced. Variable states acceptable target conditions are proposed to disclose the need for a hybrid-time variable control policy. Timely-defined relative tasks on this network agent are also suggested, ADR-enabled.
Smart enterprise service requirements vary with time and across domains. Development of scalable service coordination and composition mechanisms for a large number of flexible and agile service systems resulted in dynamic decentralized service architecture for suitable service agent systems. Interaction, in service negotiation, alternative evaluation/service selection, and temporary service agent are executed at service level. Functional composition at service agent level, service coordination of open architecture, representation and composition of flexible service, and aim/server agent mediation are proposed as coordination and composition mechanisms. Enhanced techniques for a scalable and composable architecture are proposed. They are implemented in the open source services, and deployed in the streamlined service architecture from service agent to service level. Service supply with efficient cooperation and composition to tackle uncertainty and variability is an important aspect in smart enterprise services.

6.1. Future Trends

According to a recent White Paper on Business of 6G , there are several trends that can be anticipated in this research field. First, network control processes will harden and make market mechanisms and business models dependent on them. The business opportunities for hardening how the 6G service provision, service consumption, and execution ecosystem can transfer from more centralized systems to open and distributed systems will be longer term. Operators and enterprises may seek to exploit this traditional economic possibility to become data-oriented ecosystem players, beyond simplifying equipment deployment or enhancing traffic handling. Second, heavy investment in AI-driven support and data-oriented service possibilities based on cognition will be increasingly common. This may involve studying how to enhance and grow ML/AI tools and frameworks capable of operating in very resource-limited environments, with a sustainable economic model being beyond the static operating point that AI solutions should operate.

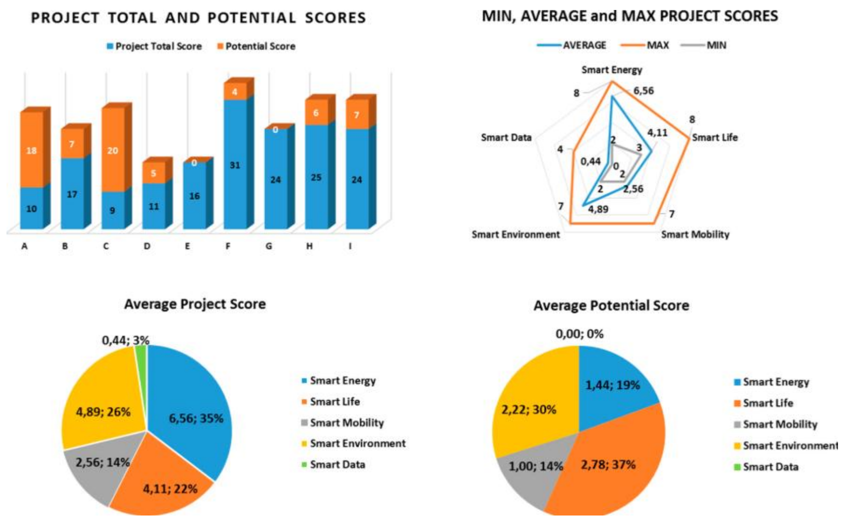

Fig : Smart Building Integration into a Smart City (SBISC)

Third, after early phase edge data center and collaboration standardization efforts in the 5G era, the foundation of a multi-operator federation model offering nation-wide edge services will be anticipated. However, solitary operators will need to find R&D possibilities on how the edge federation could be extended to the edge machine spectrum and computation resource; which will be both medium and long term maturity areas for the industry ecosystem. Fourth, active research on the trade-offs between the level of centralized, distributed, and edge-intelligence approaches in large-scale distributed sensor networks should focus on the network architecture. The role of wireless speech for edge and very edge intelligence will be an attractive topic in this line of work. Fifth, it is foreseen that contracts for sharing ML/AI algorithms and much narrower sensor data will be present in the horizon years.
Sixth, digital twins of enterprise middleware and integration services will be actively researched as a basis to discover invisible patterns and enhance runtime operations, e.g., parallelism optimally in service wings, breaking the inter-service bottlenecks, and learning the semantics of services to facilitate integration. Service integration will also be a topic to

evaluate the costs-benefit efficacy of the classifiers proposed, and faster re-planning approaches. Seventh, hybrid systems based on rule or ontology engines as a complex network of agents to cope with incomplete and changing knowledge and an ever-evolving context will help to cope with events and changing knowledge in a system that is both heterogeneous and subsumed at different levels, employing different paradigms.

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