

Expanding Telecom Network Range using Intelligent Routing and Cloud-Enabled Infrastructure

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Abstract

In the recent years, in mobile telecommunication, changes in the market, regulation and technology challenge telecommunication operators to steadily reduce their costs, service delivery time and time-to-market for new services while at the same time ensure a certain quality and reliability of their service offers. These conflicting challenges are hard to meet with the current, over dimensioned and inflexible infrastructure setups built up over many years. A paradigm shift is needed leading to a transformation of the current telecom operator ecosystem into a fully fledged cloud enabled environment in which resources can be dynamically provided on demand in a more cost-effective manner. The potential of Media Resource Function as a Service (MRFaaS) deployed on a cloud-enabled infrastructure is proposed for a cloud based, telecommunications area view. Infrastructure level parameters are described and configuration scenarios for a T-Systems Deutsche Telekom mobile network are outlined.

Cloud computing, as a new paradigm in distributed computing, promises to provide an enterprisewide flexible utility with on-demand provisioning of resources, allowing providers and users to access their own resources in a virtualized manner. The cost-efficient provisioning for on-demand resources is a prominent advantage of cloud computing together with its flexibility to scale up and down resources. The bandwidth for mobile communication is limited and expensive, which means it needs to cost at an optimal level. The main know how of telecom operators lies in controlling the bandwidth paths to connect users to destinations at a certain quality level. After resource requirements have been predicted based on traffic and users at each point in time and matched with potential provisioned resources, the cost of the current configuration assigned to the demand is calculated. In addition, optimization, evaluation and answer validation of the mentioned model are shown later in the paper. Compared with the original MRF configuration cost, the solution costs 232, 886.76 € less in total, revealing the perishability and suboptimality of the original configuration.

Keywords: *Telecom Network Expansion, Intelligent Routing, Cloud-Enabled Infrastructure, Network Optimization, Telecom Scalability, Cloud Computing In Telecom, Smart Routing Algorithms, Network Coverage Extension, Software-Defined Networking (SDN), Edge Computing, Dynamic Path Selection, Cloud-Based Network Management, Telecom Infrastructure Modernization, Adaptive Routing, Distributed Networking, Network Flexibility, High Availability Networks, Cloud Integration, Network Resilience, Connectivity Enhancement.*

I. INTRODUCTION

In this paper, a novel intelligent router framework to extend the telecom network range is proposed. To handle massive usage of bandwidth-intensive applications, the concept of a smart router is presented. The proposed intelligent router framework with service functions is

considered the system backbone and a disseminator of the services. The framework architecture also includes a cloud-enabled software architecture. The significantly less expensive smart routers can be added to a basic telecom network to extend its range rather than replacing the network entirely or selectively adding very costly traditional routers.

The intelligent routing is carried out by the software service functions and can be changed dynamically in the cloud.

A simulation experiment demonstrates that significant improvements in the vehicles' data and video signals in terms of roundtrip delay and throughput can be achieved using the proposed intelligent routing scheme over other alternatives.

The proposed frame contains two parts: the hardware router frame and the cloud-enabled software architecture. The smart router hardware can be cost-effectively manufactured to perform only layer 1 through layer 4 functions. The upper layer routing functions are done in the cloud that is realized on a cluster of x86 servers with Intel processors running Linux.

The proposed architecture can be added to and interconnected with a pre-existing telecom network. They are elaborated in the following two sections along with the routing service functionality of the proposed hardware and associated cloud-enabled software architecture. The software architecture that runs on a Linux system is a cloud-enabled intelligent router architecture for inter-vehicle communication. This architecture aims to provide intelligent routing services to forwarding nodes for data messages and video signals.

II. UNDERSTANDING TELECOM NETWORKS

When using AODV routing, the shares are routed from the source to destination without even a single packet being lost. According to the assumption discussed above, the entire bandwidth of the network is utilized for communication. However, some packets can be lost when using DSDV routing, which is caused by the difficulty associated with collision and share reinjection. However, in DSDV routing, if few packets are lost, this can be compensated with the adjustment of packet size and a proportion of packet re-generation. Although the DSDV routing method has the drawback of packet loss, DSDV is considered as an effective method for shorter distances. Since the network consists of ant colonies, the nodes employed classical telecom unicast routing, according to DSR with the added modification of "ant". This method looks for various paths to reach from the source node to destination node without any interruption in a time less than a single packet delay on average. Under the approach for timer setting discussed above, either both DSDV method and AODV method produce a single ant packet or stop the ant routing activity where the packet size of data share is larger than a critical point. Since the ants travel at a lesser speed than data packets, competition for the first arrival at destination comes into play from a network perspective. With regard to effect on packet drop of longer distances, it is predicted that there will be substantial differences between ant routing protocols.

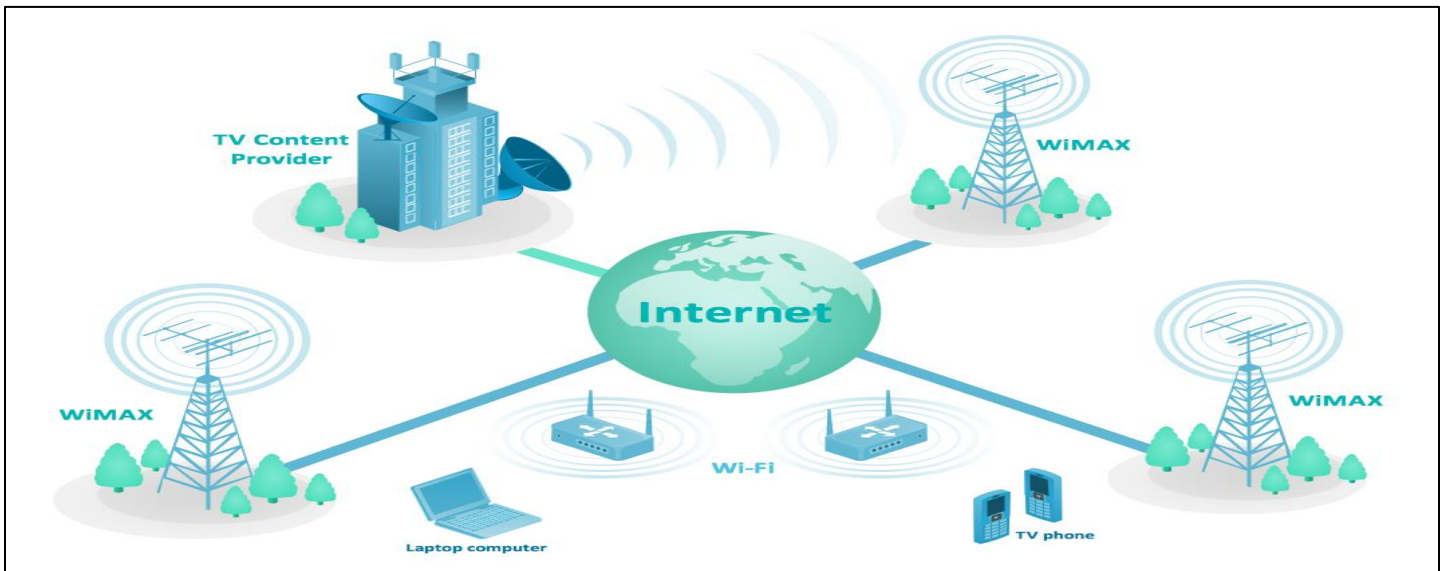


Fig 1 Telecommunication Network Diagrams Solution

As a relatively extreme example from a macro network perspective point of view, the length of the network from west tension to Mecklenberg appeared to have about the same competitive space for a variety of routing protocols. As with contention based routing, fairness may be requested for a node based on the rationale identified by simulations of an active measure of packet through put. There is an infinite buffer network which is capable of adjusting the

communication quality of packet voice data by modifying ratio of data share and packet drop. New methods for performance enhancement of scaling up and expanding the telecom range are proposed using intelligent methods in routing protocol. As a natural outcome of this process, a new hybrid algorithm is derived by combining DSDV and AODV routing, which can provide broader high quality service underneath in a reasonably large network. Additionally,

expense cost can be reduced by cloud-enabled infrastructure newly forecasted to significantly allocate computational resources.

III. CURRENT LIMITATIONS IN NETWORK RANGE

The growing demand for higher bit rates calls for new technologies and regulations in the Telecommunications Industry since the already allocated spectrum is overcrowded [2]. Similarly, ubiquitous networks have not yet been achieved due to the impossible coverage solution by cellular networks alone, where it has significant costs on both Capital Expenditure (CAPEX) and Operational Expenditure (OPEX). In ad hoc Networks, however, a collaborative model of high-altitude platforms such as small UNMANNED AERIAL VEHICLE (UAVs) network requires no prior infrastructure and coverage could be dramatically extended by exploiting both LTE and 5G RAN of macro BSs. In this way, LTE based UPLINK (UL) relay networks have already been studied by mainly performing analytical investigations.

On the other hand, to boost the capacity of the telecom services universally, Broadband coverage to airborne systems via ground-based cellular networks is indeed a promising candidate to possibly circumvent such needs. However, this advantage comes at a cost since the high speed of airborne devices (A-UEs) limits the uplink range due to the fast link variations and the practical coverage requirement becomes challenging. This work proposes some methods to effectively study the impacts of a large number of antennas at the ground-based base stations (G-BSs) network to the range extension of ground-to-air communication environments. Since the mathematical

framework is really complicated, there is no hope for an analytical insight, but the proposed workings are expected to grow as a balancing effort to make the analytical studies of the similar environments by presenting relevant results first. The usage of a mathematical framework is investigated for any general description of ground-to-air environments using tractable parameters. The main focus areas include deriving sufficient conditions on should-be tractable parameters for the airborne systems to impact the computational speeds and determining the analytical expressions of the mathematical characteristics based on the tractable parameters. The proposed models could provide effective platforms for the design, the analysis, and the performance evaluations of the considered environments of airborne systems. Though it is a very early stage of research into airborne systems for the community, there is still a hope that the mathematical framework may nudge the research effort into previously untapped vigorous topics of airborne systems at larger extent.

IV. INTELLIGENT ROUTING EXPLAINED

To accommodate a large number of users in a mobile network, increasing the capacity of radio base stations is not sufficient. This gives rise to a need for intelligent routing so that each user can access an available base station that is able to accommodate it. It is then assumed that there is enough backhaul capacity available to connect the users to the core of the network, where each base station connects to one or more base station controllers via a transport network operating at a much larger bandwidth. The scheme proposed also relies on the availability of sufficient internal capacity in the transport network, but the mobile operator may need to reallocate traffic in the event of call failure or excessive delays.

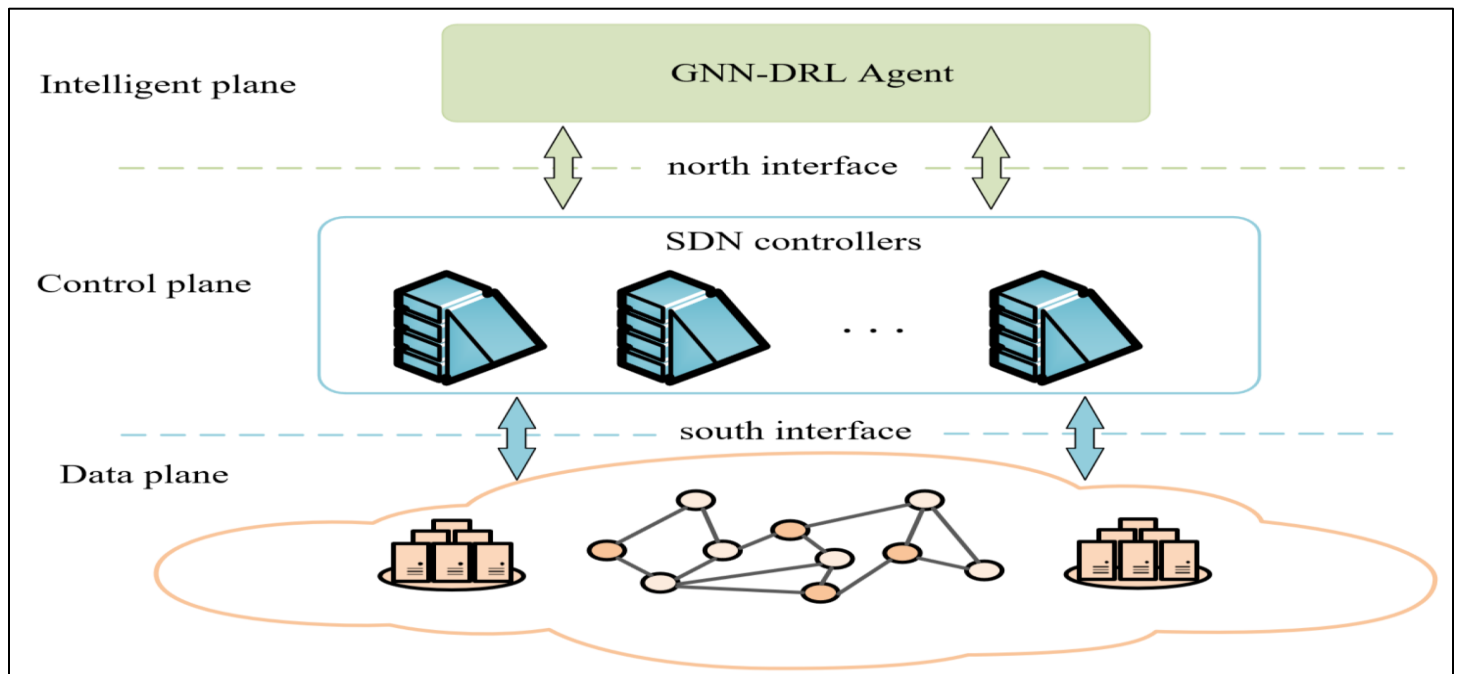


Fig 2 Research on Generalized Intelligent Routing Technology Based on Graph Neural Network

Router network closures have attracted much interest recently, for public service management efficiency and resource constraints implementation. Multi-wavelength routing in optical networks has also been extensively researched lately, including linear, path, and round-robin demultiplexing schemes. However, there is still a lack of good performance for most ratio-greedy assignment strategies, especially for high arrival rates or network load. An improvement introduced is considerably better in maximizing throughput and also in the arrival rate where the problem is fractal. There have been several insights on routing policies that demonstrate how learning can significantly improve performance.

However, a significant efficiency drop occurs as the allowed latency and cost bounds are decreased, and on a few difficult cases, optimal settings are not obtained. To address these limitations, a new meta-policy construction that selectively chooses the best fitting simple policies is developed. Empirical measurements and simulations confirm that meta-policies outperform existing optimization methods even on heterogeneous systems. Given that the suboptimality of simple policies and their composition in optimal solutions are also investigated analytically, the new meta-policies yield an effective learning scheme that is capable of robust performance while exhibiting low complexity, for very large state spaces.

➤ *Routing Algorithms*

Potential problems and solutions regarding network capacity expansion are proposed. The cloud-enabled approach to expanding network coverage, specifically deploying new base stations (BSs) in the network, is enhanced using intelligent routing algorithms and cloud-enabled optical transport. Potential approaches to deploying BSs in the optical network are reviewed, including methods based on the analytical approach and arrival-loading approach, incorporating various parameters such as coverage area and load balance. Proper methods are identified to enhance the BSs' availability in the network. Using that, a mechanism is proposed to expand BSs' availability in the cloud-enabled optical transport network. It is further extended to optically-connected scenarios providing extra features in cloud-enabled networks. Network-less scenarios, e.g., upon suddenly arriving events or rapid congestion of deployed BSs, are also addressed using additional routing algorithms and a re-deployment computed mechanism. Both scenarios propose various efficient algorithms ranging from exponential-time complexity to optimal, easy-to-implement algorithms, as well as further enhancements over the base case.

A mechanism of intelligent routing is proposed to ensure both overall load balance and latency reduction in wide-area BS-non-connected scenarios when the potential density of the wireless network is increased. As the coverage area given to each BS decreases, network-related quality metrics tend to degrade, resulting in longer distances

between BSs and user equipment (UEs). An intelligent routing mechanism based on signal delay and inner data traffic is proposed to increase the potential transmission routes involving overall load reduction. A key point of its implementation is identifying the best expansion rate of traffic balancing across the paths and links. Instead of equal data traffic receiving, critical metrics are proposed to address the problem of effective complexity, which provide two optimal state-performance windows with exponentially lower running time complexity. The routing protocols of the common digital flood scenario are briefly reviewed. Simulation tests based on a modified approach demonstrate significant performance improvements regarding latency reduction in various scenarios of network size and traffic intensity.

➤ *Dynamic Path Selection*

In today's highly advanced telecommunications networks, the major concern is to maintain optimal Quality of Service (QoS) for their subscribers. Due to the substantial increase in data demand over the last decade, even after increasing infrastructure capacity, the switching nodes of these networks got congested. As a result, providing services like video calls, video on-demand, live content streaming, etc. has become more difficult. Optimizing the bandwidth resource while maintaining QoS parameters is an ongoing major challenge in the telecom industry. Their utilization impact also has a critical effect on the Quality of Experience (QoE) for OTT based subscribers of these telecom networks. Prioritizing the allocation of any available bandwidth among the requests at different switching nodes based on certain criteria like age, requested bandwidth and holding time can result in a more optimized allocation process yielding optimal performance statistics of the requests of any probabilistic patterns generated.

Equation 1 Link Utilization (LU)

$$LU = \frac{T_{used}}{T_{capacity}} \times 100$$

- T_{used} : Current traffic on the link
- $T_{capacity}$: Maximum throughput of the link
- Paths with high LU may be avoided in dynamic selection

This work discusses the dynamic path selection (DPS) algorithm that is used to increase the number of requests being admitted by the telecom network while maintaining the previous level of QoS at the node of any bandwidth request. The dynamic selection of candidate paths provided as input for the priority-based allocation procedure can yield a more optimized set of candidate paths based on recent successful service history, thus yielding a lower probability

of rejection for any randomly chosen requests. The performance impact generated due to flaws on the allocation process has been discussed considering all types of flaws like capacity constraint, improper priority assignment or adding additional nodes again to the routes of all failed requests. It is experimentally shown that optimizing either of these major constraints based on any probabilistic patterns of requests can maintain the previously maintained levels of performance statistics.

As the service time increases further from some certain threshold min value, an increase in bandwidth request's acceptance ratio (BAR) will yield a parallel decrease in its QoS violation probability (VP). Overall, this work shows that the augmentation of the telecom network infrastructure is no longer the only answer to achieving subscriber satisfaction. Instead, prioritizing, better allocation and enhancing the scheduling algorithms in the control plane of the telecom networks can also yield satisfying results, which are mostly unexplored areas in this field.

➤ *Load Balancing Techniques*

This paper reviewed capacity expanding techniques and service delay improvements of telecommunications network under cloud and SDR based architecture. Without degrading blocking probability, two promising directions were selected and research results are reported. It is expected that hybrid telecommunication network composed of cloud enabled infrastructure and intelligent routing will serve rapidly growing data demands. Based on cloud enabled infrastructure, SDN regulated intelligent routing equipped relay capacity expanding techniques were proposed for the service delay improvement issue in telecommunications network. Simulation results have verified that the proposed techniques can be used to efficiently protect transmission service delay performance against network capacity overload. It can be expected that networks consisting of distributed cloud servers together with SDN based intelligent routing equipment will be a major part of rapidly evolving communications among cloud computation service applications, computers, smart terminals and other devices. This type of hybrid networks is expected to have high competitiveness over existing telecommunications networks in terms of growth of data traffic demand and network service delay improvement techniques.

Two significant fields of network evolving are discussed in this paper. As cloud enabled optical networks disperse network infrastructures and cloud servers, on demand resources and capabilities should be explored with controllable scale. SDN usable routing techniques are first reported as an appealing solution. On the other hand, telecommunications networks should provide improved transmission service delay. On demand capacity expanding techniques enabled by SDN based data computation are reported in an example. Most of the papers focus on service capacity network expanding. However, the wider scope of telecommunications service delay performance

enhancement is acknowledged to bring a lot of meaningful research passion and opportunity. Many promising techniques are still highly beneficial from both theoretical development and industrial innovation perspectives. New discoveries and applications through interdisciplinary approach and collaboration could achieve an unbounded upper ceiling to telecommunications network developing.

Intelligent load balancer is the core of the proposed routing schemes, which uses network knowledge as well as dynamically tuned heuristics to distribute traffic on multiple paths. Load balancing is an important mechanism to improve the network utilization and provide better service to users. An adaptive load balancing technique for Diffserv networks has been proposed. Instead of fixing the destination end system on a per-flow basis, the optimum switching paths between an ingress provider edge router and an egress provider edge router, which utilize as many free resources through the network as possible, are determined.

Equation 2 Load Distribution Ratio (LDR)

$$LDR_i = \frac{L_i}{\sum_{j=1}^n L_j}$$

- L_i : Load on server i
- n : Total number of servers
- A well-balanced system will have $LDR_i \approx \frac{1}{n}$

V. CLOUD-ENABLED INFRASTRUCTURE

Infrastructure for radio networks is very different from traditional IT infrastructures. Several devices are added to the traditional server-client chain in the control and user plane, the so-called base station (BS), where most of the cleverness and functions are located. Different BS have different capabilities, from small femto- or picocells for indoor coverage to large macrocells for high power consumption. The latter can incorporate elements such as a baseband unit, radio equipment control, or additional service equipment. This additional equipment normally resides in a secondary site with a C/RAN approach. This infrastructure enables many additional applications outside traditional telecom services, like virtual coverage service, or DAs for private networks [1]. However, these resources can seldom be coordinated because they reside in different entities who commercialize independently and have extreme inertia.

With telephony operators, the delay in deploying new technologies meets the expectation of serious regulation. An example of a network-based technology is the VoIP. Again, VoIP-based applications for business and corporate users are in demand, but there also are needs for low-cost telephony services for basic needs. However, innovations in this direction do not surface because exploiting a traditional network involves extraordinary efforts in reengineering and financing new technology, which exceeds what is considered reasonable for telecom carousel data. Under these circumstances, the applications surfacing social needs are a good opportunity for telecom carousals to upgrade and expand. Nevertheless, the C/G architecture faces important challenges like dynamically using cloud-enabled infrastructure at secondary sites.

➤ *Overview of Cloud Technologies*

The components of a telecom network can be divided depending on bandwidth and latency parameters into core (backbones), which are typically made of fibre links, metro (backbones), where WDM rings are often deployed and which connect secondary to primary sites, and access networks (cellular base stations, DSLAMs), which are mostly based on copper or radio transmission. Primary sites typically host a routing platform (which consists of one or more core routers and an IP backbone) and serve hundreds of individual access speeds via hybrid networks made on different technology (in DSL or fibre) and composed of concentration nodes, secondary sites, which connect over metro/suburban distances via point-to-point WDM to the primary sites. Cloud-enabled infrastructure covers over a set of geographically distributed cloud sites, which connect to telecom networks, Internet Exchange Points (IXP), content delivery networks (CDN) etc. Secondary sites are typically much smaller than primary sites and host network equipment like media gateways (MGw), radio network controllers (RNC) or base station controllers (BSC). Secondary sites connect to external networks via the primary sites they are connected to. Secondary sites are mosaics of metropolitan telecom networks composed of dissimilar fibre and copper backbones which enable content and service “diffusion” in the neighborhood.

Middle-field routing has to deal with highly heterogeneous routing domains, which cover both metro and core spawning and pricing of paths to a user destination “session”, or more generally a traffic matrix among all networks’ terminals. Routing in telecom networks is typically made over dedicated leasing. This is usually made referring nodes to internal routes (MPLS label switching), which is a path of routers interconnected by point-point links in the forwarding domain. Telco do not own all routers or links in the transit routing. Leasing is only a fraction of the incremental cost of a route, which is composed of its hop count (the number of router on the path) and reactive costs like congestion, whereas the monthly cost is composed of fixed fees based on price buckets and penalties over contracted performance (like blocking or QoS consideration) of during the month time intervals. Cloud Computing is about the paradigm of offering computing resources as a Service in a flexible way [1]. Cloud computing technology is finding its way into telecom networks because of its increased flexibility, cost efficiency and potential to enable new service offerings. The virtualization of network services may lead to a more efficient utilization of resources as well as a reduction of energy costs. In this paper, the notion of a “Telco Cloud” refers to a telecom network in which IaaS resources such as virtual machines can be spawned as a Cloud service inside sites, in secondary sites or even at base stations. However, this is only true as long as we are only considering cost for processing and not the costs for networking.

➤ *Benefits of Cloud Integration*

By incorporating additional layers into the model, the framework can easily be extended to other combinations of different virtualization, since only minor changes are required. For example, 3G and 4G processing with low and high bandwidth streaming. Software based switching would be feasible for 3G or a combination of optical switches on the back end of the 4G equipment can be examined.

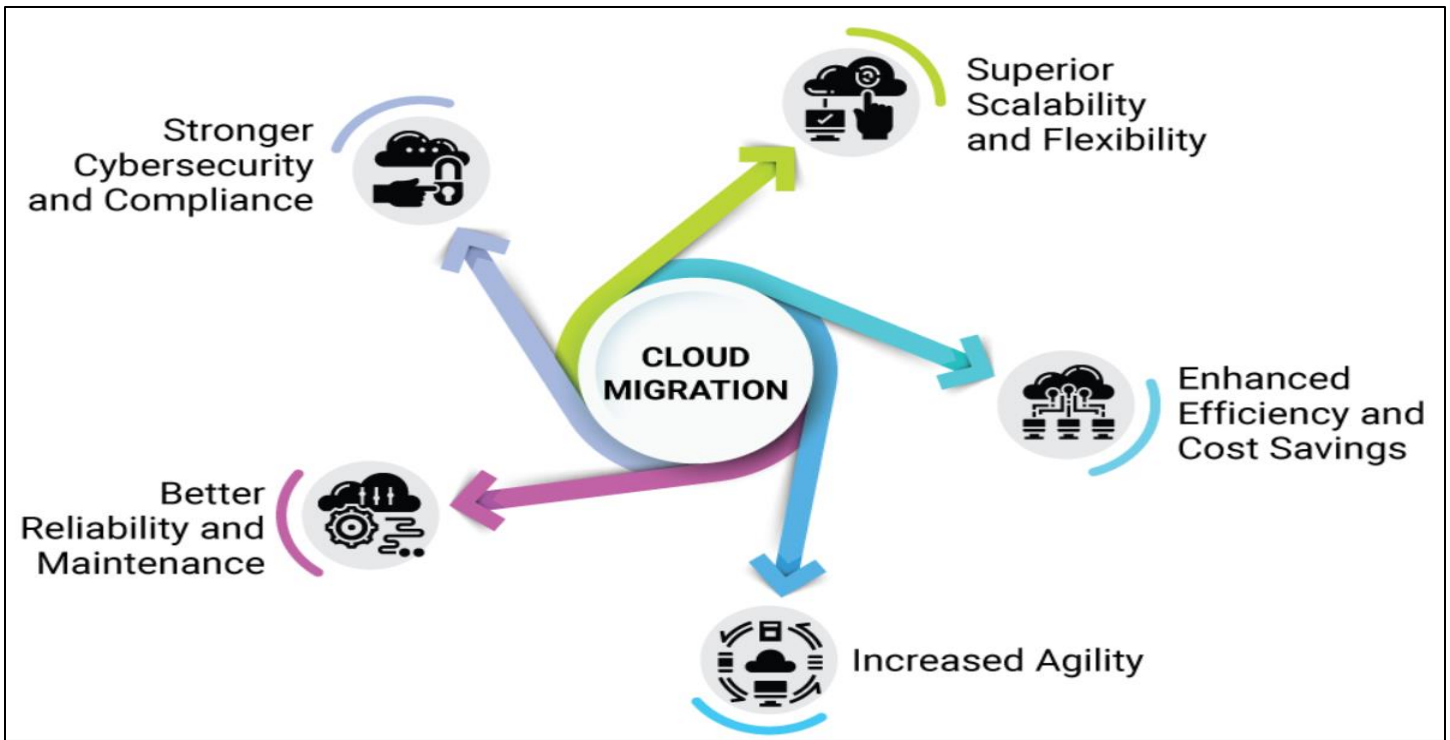


Fig 3 Key Benefits of Cloud Migration

Operators can make informed decisions about the management of cloud services across multiple circuits based on this comprehensive approach to system integration with smart routers. Such intelligent routers are often implemented as part of the cloud’s core processing. Application agents can be distributed across several hardware platforms from a host server to a component cloud. A framework for integrating hybrid clouds based on shared and dedicated components as well as public, community, and private networked operating domains. Existing networks can be upgraded to accommodate VC with SC entities in order to register for a larger set of operations. Afterwards, operator-selection routing can be employed across the connected SDN.

The underlay operator’s capabilities are exposed as services to the overlay SC agents. Services can now be requested from the underlying data carriers and combined with redundancy for a wider range of QoS, including additional generic constraints. This ensures SC is always achieved. Infrastructure is acquired internally or externalized through a resourcing broker. Queueing models can be employed which uses SDN to manage the dynamic routing and forwarding of traffic across diverse services implemented on the network. With SC incorporated in telecommunications architecture.

➤ *Scalability and Flexibility*

In the realm of telecommunications, the transition from traditional to cloud-based network infrastructures continues to gain momentum. A need for intelligent routing and service deployment management systems has arisen, spurred on by live cloud event processing and routing infrastructures. As networks evolved to utilize many more nodes and extend

beyond the service providers’ domains, the complexity of packet routing has grown exponentially [1]. In particular, packet routing rules, required to deliver packets along the predetermined paths, quickly became non-scalable in the naïve form, stored in separate tables deployed on many IP nodes. Consequently, administrators spent most of their time devising these rules, manually setting them in the routers, and subsequently maintaining them within necessary bounds after each network change. To remedy this problem and return to a state where provider’s capacity and flexibility on how they shape and size their network are on par with spend-out, the work presented new concepts of intelligent packet routing. They leverage on the transition from traditional routers to cloud-based instances and reframe old problems into new ones by using less segregated ways of managing how paths are calculated, and what network events they react to. In turn, essentially different logics can be realized that help preserve path integrity and expedite routing correctness.

Modern telecom networks consist of an ever-growing number and variety of nodes/entities connected through high- and low-capacity links. Human administrators need to prescribe routing rules to allow network entities to send packets along predetermined paths. However, this approach quickly becomes non-scalable as the number of nodes and links increases since many rules need to be stored in tables that must be deployed on IP routers. Nevertheless, in the near future, it is expected that common cloud concepts, such as hyper scaling and virtualization, will be incorporated into telecom networks. There will be many providers each consisting of many geographical data centers, each containing hundreds/thousands of blade servers. A need for intelligent routing and service deployment management

systems arose, which were spurred on by the development of these cloud concept's live event-on-the-fly processing counterpart.

Equation 3 Scalability Factor (SF)

$$SF = \frac{P_n/R_n}{P_0/R_0}$$

- P_n : Performance after scaling (e.g., transactions/sec)
- R_n : Resources used after scaling (e.g., CPU, memory)
- P_0, R_0 : Initial performance and resources
- $SF = 1$: Linear scalability; > 1 : Superlinear (excellent); < 1 : Sublinear

VI. COMBINING INTELLIGENT ROUTING WITH CLOUD INFRASTRUCTURE

One area already subject to intensive research is such a hybrid telecommunication cloud service that provides

efficient transport of multimedia streams from content servers to consumers. These are messages of a defined structure desirable for named users and produced by dedicated source nodes. Possible applications include TV broadcasts, video on demand or user generated contents, online games or stockmarket price feeds. The associated conveying transport paths take seamlessly advantage and benefit of all existing telecommunication infrastructure. They span primary and secondary core nodes; those that implement IP particular containers that transport the embedded multimedia message streams [1]. The basic working method of the approach is as follows: Upon receiving a retrieved publication announcement, all routing calculus output but those for the core unicast paths are discarded. The nevertheless controllable source/unicast nodes are treated as the Publication source; all signalling messages are looped over to the destinations from them until an already existent path is asserted or the consumers have received the stream. All destinations are informed about that via a non alarming notify message. Arguments are given why this invention does safely level control of an existing content delivery service without jeopardizing the assurance of reliable delivery of its messages.

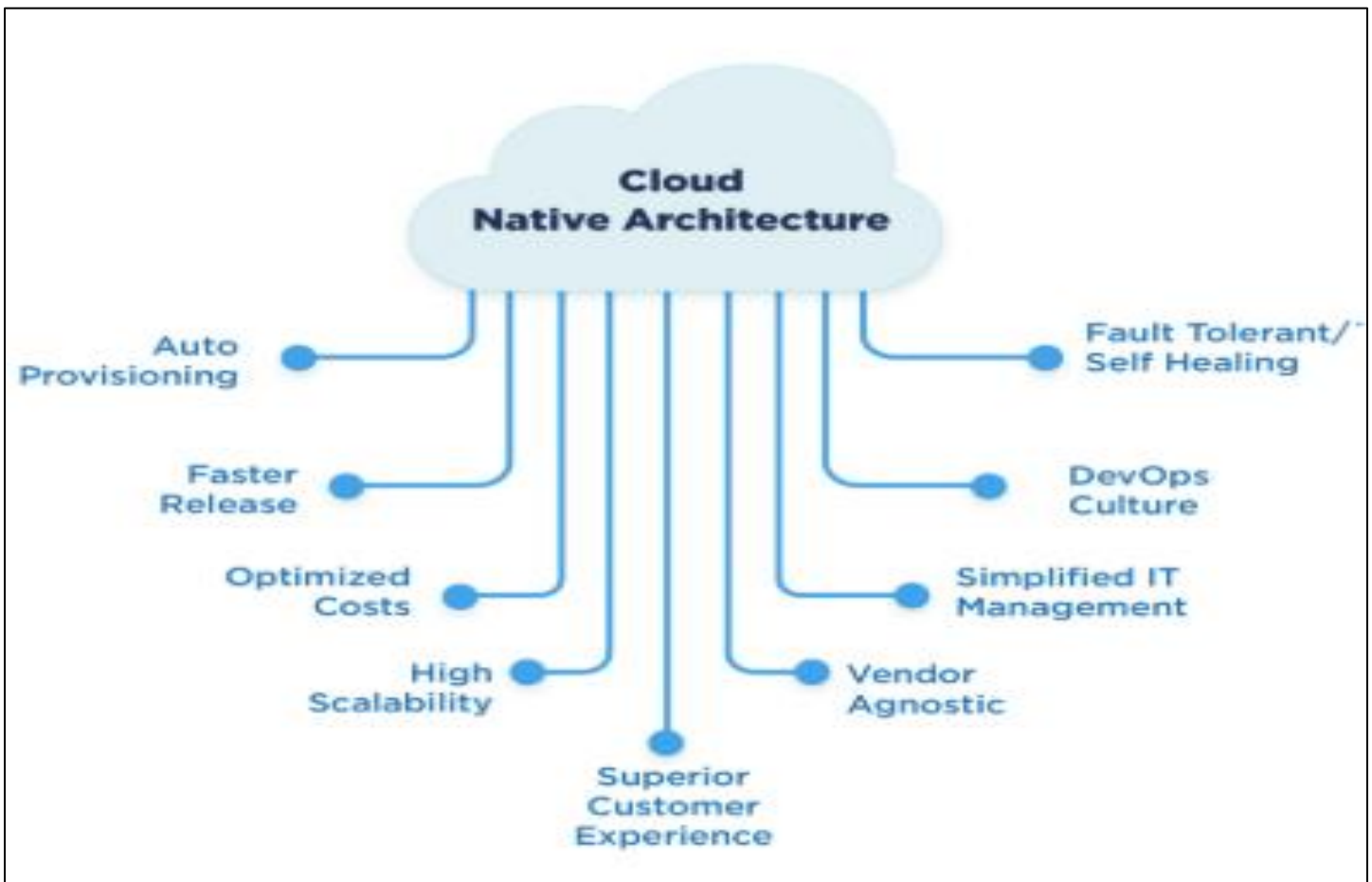


Fig 4 Benefits of Cloud Native Architecture

However, excessive out-of-band monitor traffic must not disturb the original online video on demand service and other applications presently served by the networks. This

poses considerable algorithmic challenges. Two-layered top down network measure computation accounting for efficiency issues is given. Strictly above all concrete prod

attributes considered in design heuristics are inevitable for experimentation. Ultimately, as an own invention a hybrid page generator for at least some tests utility is proposed. Together with a novel way of keeping pair-wise already considered network measure indices up-to-date it answers the question of network and consumer statics for whatever given method. The particular state is made accessible. Because of the manifold yet mostly My understanding is mainly conceptual issues and of academic character. Hence, wherever useful pseudo pre-conditions conducive for any research project are formulated. As such they are conceptually necessary but have also substantial engineering meaning for the present development at least in as far can be achieved.

➤ *Synergy Between Routing and Cloud*

Telecom networks with global reach are typically built up from a multi-tier architecture. All subscribers connect to a set of access nodes that aggregate traffic towards an IP backbone. The interconnection of all access nodes to the core IP backbone and the connection of the latter to international carriers restricts the design of the core network and is often treated as a static backhaul design task. Using graph algorithms, a primary routing can be determined before the network is built. The remaining routing, such as the assignment of edges to adjacency pairs, can however be automated again. Indeed, engineering, configuring, and fine-graining a large telecom network can take decades. Current macro base stations, however, represent isolated islands of traffic until a user is on-hand. This yields wasted resource and delayed switch-on under a flexible infrastructure. At any instance, there could be neither signaling nor baseband resource to support a potential hand-off below the channel rate resource. Similarly, provisioning in a cloud context is presently limited to non-cognitive and non-automatic configuration.

Cloud-enabled infrastructures may facilitate dynamically forming a base station and routing traffic to it. With traffic fair-rate spread across switches and flows, the facility can be reused base stations. The optimally placed and routed placement would depend on a combination of traffic variations across scales and of evolvable mean channel strengths. Such amortization can benefit from unifying the resource for Baseband Unit and Application, thus complementing to an overall signal-processing optimum. In conjunction, adopting all-optical switches can eliminate the cell delay problem due to blocking at space switching, enabling a more effective first-in-first-out queuing in timeshared wire-spine routing. This affords dynamically provisioning gloss signs not only at wavelengths but at rates across trunks.

Unlike in the core IP domain, application-awareness can be harmonized with scalability through sharing a plan via a compact graph, not requiring knowledge of every edge at every node. All the nodes, switches and routers could be made Application-Aware. Nodes can schedule and take

backlog aware decisions on their processing pipeline timing and queue mapping as simply as curving a 3D graph in 5D space. These cross-layer feedback nodes embrace the whole system interconnect. They complement to and benefit from an earlier automaton capable of making distributed decisions across every signalling-aided edge. The unified and expanded capacity of switching and storage can delay switching and hence common queuing disciplines could be empowered, while a real-time viewed guarantee should emerge on loss and jitter.

➤ *Case Studies of Successful Implementations*

The rapid growth of telecommunications in the past few decades has presented unprecedented challenges for telecom network planners. A perennial problem is how to extend network range without increasing operational expenditure, and how to address coverage holes. Recently, a solution proposed involves placing low-cost relays/routers, designed as intelligent devices that aggregate traffic from client nodes and relay it to a central syslog server through a backhaul link, within Wi-Fi coverage holes.

This scheme would have multiple benefits. By generating backhaul connections to the collect nodes, this scheme could not only increase the network coverage range but also enhance clients' video streaming experience. Those benefits can be particularly apparent in news hot-spot sites, such as sports matches and political rallies, where massive numbers of crowds get together and generate tremendous impact on the video, voice and texting services. Average client video experience bandwidth is tremendously improved in a better coverage environment. Clients benefit from smoother streaming and fewer interruptions of packet losses. Furthermore, the backhaul load is also balanced by 52% with extremely uneven by the improved intelligent load-adaptive routing algorithm.

An intelligent-relay-facilitated Wi-Fi network can be realized by incrementally adding i-routers into the current base infrastructure with minimum cost. With the help of such devices, telecom companies can cost-effectively expand the current coverage without installing new towers and cabling infrastructure. Rather, by opening decommissioned base stations, clients' experience is fast improved before knowledge and experience are accumulated to switch over to the more complex and costly architectures and designs even with more effective solutions generated.

VII. IMPACT ON NETWORK PERFORMANCE

The new approach helps to significantly break these two constraints. By pooling a number of agents from access network fringe and core in a telecom Network Operating Centre (NOC), intelligent agents can be more responsive to impending sliding-scale demands. When demands for services to new or additional subscribers are known, it enables on-the-spot re-routing of content and call loads to more suitable exchanges and/or larger base stations. It also

enables network convergence so that voice, video and data services can be much more responsive to subscriber demands within a greater range than have been possible before.

Thus, when and if failures occur, the early warning and on-the-spot active intervention by a local agent will usually suffice. And because there is now co-resident management of either various types of content across multiple vendor's equipment, or of a given type of content across equipment

from different vendors, the extent of the failure will generally be limited to a single equipment type, or smaller ranges of content types. For example, at the edge of the network nearest the customer, faulty base transceiver stations will be able to take calls from neighbouring stations but redirects will not be able to stop further calls seeking to use that equipment. And because these are most often the busiest and high density locations, the pink slice will mean the range of customers faulted is limited to the one base station in their coverage.

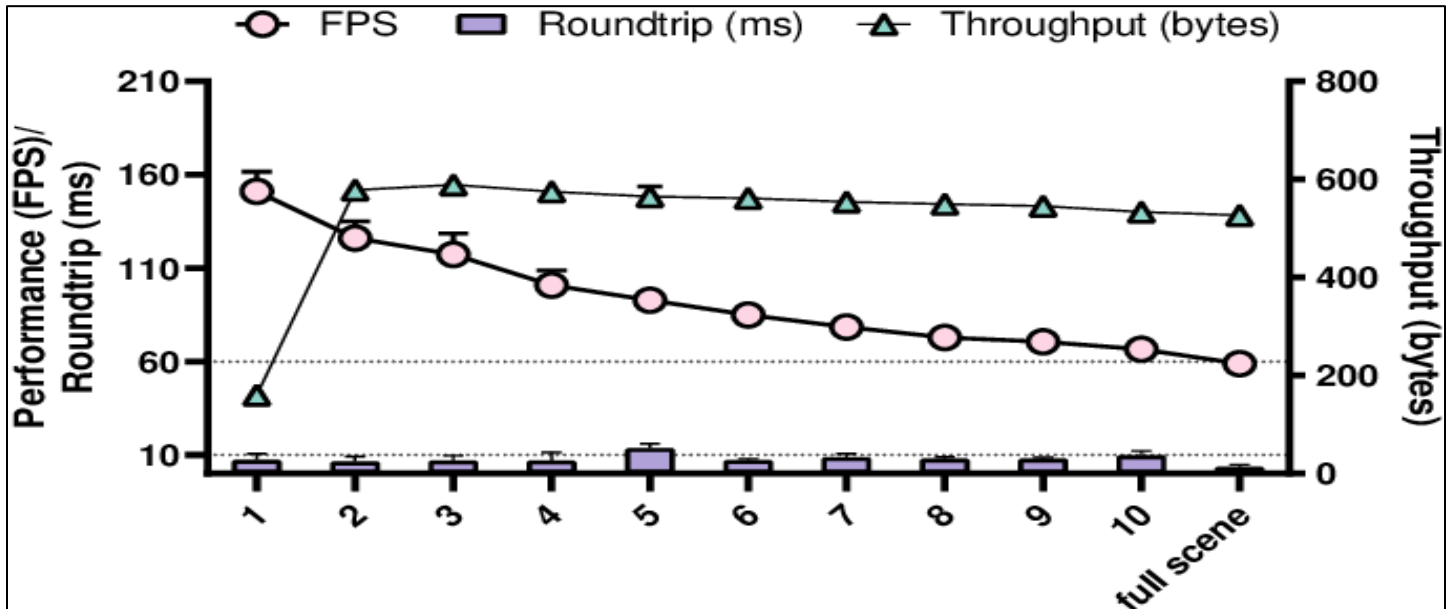


Fig 5 Chart of Network Latency and Rendering Performance as The Number of Clients Ranges from 1 To 10.

The new approach therefore allows today's operational networks to be augmented towards a more rapidly responsive and scalable architecture. New re-routing and load shedding control methods can be introduced now which will not require substantial further investments in monitoring infrastructure or extensive retraining of workforce. Instead, the methods can be applied in relation to whatever infrastructure is in place today. However, to meet the contemporary growth demands, additional monitoring infrastructure will soon be needed. Because the new architecture permits the monitoring of existing infrastructure with the gradual addition for the new generation infrastructure, this gradual, two-vendor transition is possible.

➤ *Latency Reduction*

The Internet has a number of latency-critical applications, including cloud-based controls, self-driving vehicles, augmented reality, virtual reality, and stock trading. They all have an absolute minimum latency requirement. Recent work has made significant progress on many fronts, including measuring latency; distinguishing contributions from topology, routing and transport, etc.; and improving latency through changes to transport, routing, and even application layers. However, nearly all of this work has paid little attention to what might be the largest source of

latency inflation: the underlying infrastructure and its inefficiency.

There is an enormous, untapped opportunity in investigating and modeling cost- and performance-effective improvements to the physical layer, especially in fabricating faster and cheaper point-to-point links, fibers, routers, etc. This work proposes a nearly speed-of-light Internet service provider (ISP) and analyzes its anatomy, construction methods, costs, and impact on carrying loads, etc. Speed-of-light backbones with speed-of-light routers, fiber, and customer links/premises are simulated, showing that although they are still within an order of magnitude of being speed-of-light today, they can be constructed at a fraction of the current backbone, router, and fiber costs. Quality-of-Service (QoS), accuracy of circuits, and the needs for replacing routers, etc. are also addressed. Finally, it is qualitatively argued that the speed-of-light ISP will dwarf the needs of humanity for communication bandwidth in any near-term future.

As a result, the providers will incur, at best, a mere fixed monthly cost storing a capacitance for buffering, mostly idle hardware cost, and costs for energy, land, caretaking, etc. that are magnitudes lower than those of current ISPs. In 20 years, the monthly service cost per person

in a region would be <USD 0.03, and the data-carrying volume per duration would transition from terabytes to exabytes for each person in a city. However, the task to keep the speed-of-light broadband service at a very low price is also huge, as the service would place stringent requirements on operators and edge control devices.

➤ *Increased Throughput*

Increasing the network range is directly related to increasing throughput or bandwidth. If a telecom company wants to increase the network range, it can do it in a few ways. One way is to deploy more cell towers that are farther away from one another. This is an expensive way to expand network coverage. Another way of increasing the coverage of the network is to decrease the power with which the signals are transmitted. The network coverage gets extended, but at the cost of network capacity. Decreasing the power of signals that are transmitted from cell towers results in decreasing the range at which the information can be transmitted. It is not suggested that telecom companies reduce the power with which information is transmitted as a solution to extending the range. The main proposal is to route part of the traffic to the cloud for processing using more powerful data centers. Another way to increase the coverage and throughput of the network is to deploy base stations that instead of connecting directly to the Internet, connect to nearby base stations that connect to the Internet. The ushering in is cheaper than deploying more base stations that connect directly to the Internet. It is possible to deploy such base stations closer to users and it will still be possible to extend network coverage significantly without the need for deploying new core networks. This solution, however, will introduce the problem of longer delays than what exists today. If every packet had to go through only base stations

then with the arrival of this new system, the time between the moment the packet leaves the source base station and the moment it arrives at the sink base station would increase. As the number of hops increases, the standard routing will also result in the time between sending a message and receiving the answer increasing. In other words, allowing for routing part of the traffic would result in longer delays.

By adding smarter routing with machine-learning capabilities processor to data center applications, for example transferring it to some data center that logs the date when a message was sent, the processing time would be predictable and would change as the load of the base stations changed. However, applications that are not sent to the cloud such as video calls, teleconferences and CCTV cameras do not have this property. Time on network and delay can not be predicted or even have a distribution. The only property that holds is a QoS.

➤ *Enhanced User Experience*

At present, active end users demand high quality of service (QoS) in terms of low latency, jitter and packet losses while accessing the real time sensitive applications such as audio, video, and multimedia. In order to meet such stringent requirements, suitable solutions that guarantee the QoS requirements are the key issues for the telecom network service providers. QoS refers to the ability of a network to deliver data packets. In simple words, a QoS enabled network is designed to deliver the individual packets of the application flows with predictable and reliable timeliness and is capable of accommodating a mix of service flows having different loss and delay requirements without dropping packets or unnecessarily delaying packets.

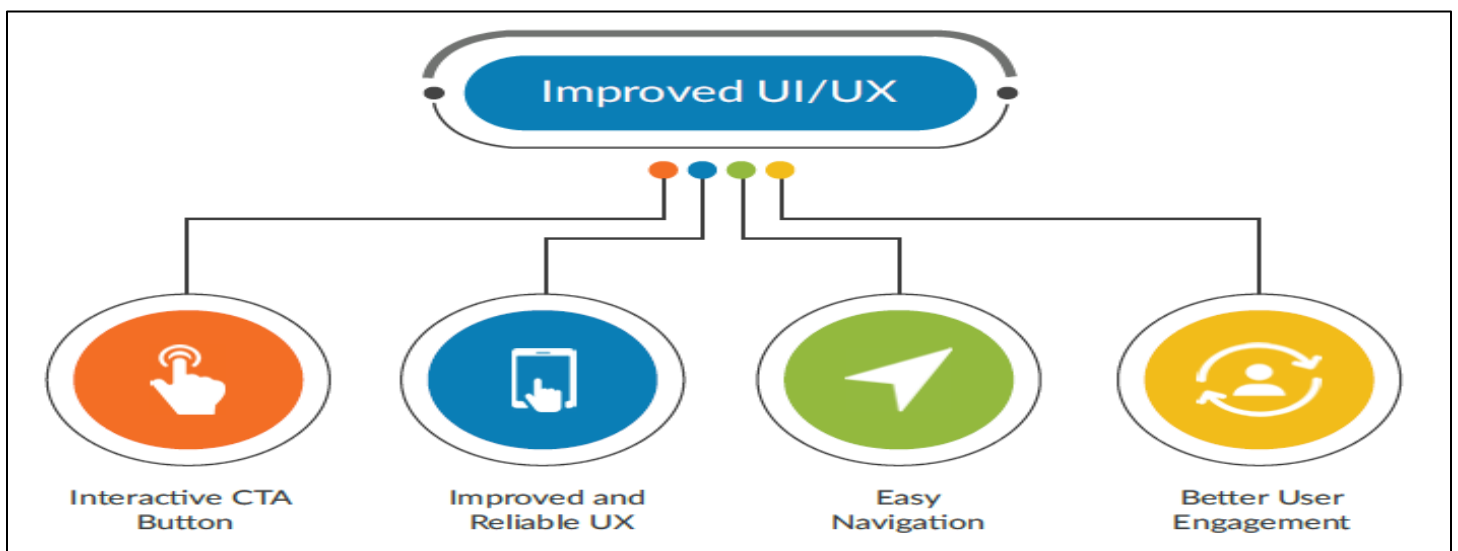


Fig 6 Improved UI/UX with Reduced Complexities for a Leading CRM Software Provider

However, assuring QoS in the telecom networks is not straightforward and involves several complexities. The fundamental problem is that either characteristics of the incoming traffic are not known or only statistical aggregates

are known. Although deterministic input traffic can be classified, characterized and forecasted for short-term (seconds to hours) time horizons with a high degree of confidence, this may not hold true for longer time horizons

(minutes to weeks) or with respect to a collection of traffics. Moreover, the complexity and the performance requirements of the rather complex signaling procedures, including the admission control and classifier, are challenging because both are resource intensive and may present a substantial load to the entire environment. The required level of intelligence needed to perform the quality negotiation and enforcement with the respective security issues, including authentication and authorization for ensuring quality expectation, resource allocation, QoS control, misbehavior detection, etc. is beyond the low-level transport domains. Further standardization efforts would be required to resolve the interconnection and interworking of the traversed access and transport domains as well as with the service-layer mechanisms. Once the various proposals have been harmonized and the standardization is completed, the various service categories of the NGN services can be considered as a collection of specialized services implemented with the already available functionalities of the NGN environment in a standardized fashion and with ensured operator-grade quality.

VIII. CHALLENGES AND CONSIDERATIONS

The selection of routing and infrastructure optimization methods depends on the characteristics of the considered scenario, e.g., the persistence of the working load on the network, and/or its careful selection. Any service class will exhibit a performance behaviour that is essentially an equivalent low order nonlinear differential equation. Besides service class, the number of batches of messages is equally important in determining performance complexity. Route optimization is NP-Hard in this multi-class batch context. Based on this assumption, a method had been developed that employs a local search heuristic as appropriate for small to medium sizes of networks.

The incremental restriction of message sizes to pairs of arbitrary ports up to the inter-exchange point within a switching fabric yields a denser complemented bipartite graph of switches and messages and edges. This graph is simpler than the original and can run route transformation heuristics by treating its vertices as oriented edges. Based on this assumption, an upper bound on the message class sizes and a time distribution interval had been developed. On any system, a bandwidth mis-match between fibers and switches enhances the computation and performance of the method.

It is favourable for the nodes of a WDM inter-core setting to use multi-group-moderate speed edge controllers. WDM is also favourable for edge-nodes of a packet switching airport or LAN. The redundancy by introduction of identical receivers and initial benchmarking on an isomorphic network-prediction are recognised to be feasible and profitable. There are in fact sufficient benchmarking nodes on-chip to measure route latency in ring networks.

➤ *Security Concerns*

Expanded fourth generation mobile communication systems (4G), now referred to as 4G-LTE, have provided mobile multimedia messaging, 3D gaming, video conferencing, etc. across the world on a ubiquitous basis. The new generation of mobile communication systems proposed by the ITU-R is the fifth generation (5G) systems. Next to ubiquitous communication, a requirement of 5G systems is to provide services or applications in a smart and intelligent manner in a socio-critical and cost-effective way [11]. Using 5G and smart technology, it is expected to create positive intelligent maritime ecosystem infrastructure by ensuring sustainable development goals. The network and computing requirements for the newly proposed concept of intelligent maritime ecosystem infrastructure are critical and demanding. However, maritime communication channels are frequently inconsistent and hard to rely on due to difficulty in heavy under-water activity. Implementing 5G systems is challenging [12]. Partially automated means of transportation are expected to become fully automated in years to come. Existing maritime regulations are not established for the automated means of transportation. Artificial intelligence-based smart maritime regulations are essential, which will significantly assist in creating smarter maritime eco-system infrastructure. Drone based docking systems and air lane communication systems are required for port development plans like air cargo ports. It is to enhance productivity and competitiveness of ports and cities. As maritime cargo contents are highly stringent and critical, it is required to consider academic, cybersecurity, hardware, regulation and budgeting constraints in modeling such a system.

➤ *Cost Implications*

As telecommunication services converge, multi-operator environments evolve in order to decrease deployment costs and offer better coverage at the same time. One potential approach to enhance the operational efficiency of service providers is the use of multi-operator base stations and RF equipment. In densely populated metropolitan areas, base stations are usually deployed in street poles. To obtain the required coverage in suburban areas, on the other hand, that kind of structures might not always suffice. As a result, base stations are often placed on top of rooftops, towers or in other "high and/or non-sufficiently accessible" structures.

Concerning these structures, a modular and intelligent method is proposed in this contribution that extends the range of base stations at a lower cost and operational complexity. Intelligent node placement algorithms distribute the networking units according to a hybrid architecture, while the cloud-enabled infrastructure connects the base stations to a common control point. Cloud-enabled network performs multi-operator cooperation and dynamic radio access technologies coordination to enhance spectral efficiency and to control interference in the same time. The contributions are multi-fold: A cloud-enabled multi-operator base station for the enhancement of coverage with low costs

and operational complexity—seamless cooperation with existing telecom infrastructures while increasing the range—achieve extensibility of network coverage without high operational costs through a hybrid architecture with intelligent node placement.

In a given area covered by a number of base stations, when a new base station is required, the method chooses a new base station from a number of candidates according to a fixed criteria of cost, higher level of load or potential of the coverage increase, etc. If no base station candidates are sufficient, it connects sub-areas each of them covered by at least one base station together with links to a central point. A hierarchy of signalling and connection routes is performed—segments covered by the same base station follow the metric, others are selected according to the end-to-end delay, the number of hops, or system load.

➤ *Technical Limitations*

The basic MTE, geohyperbolic (or hyperbolic) space, renders the network with scalability and self-organization that eludes conventional topologies. However, active geo/physical routing protocols that implement MTE and its coordinates need further investigation. Resulting forwarding table sizes might be significant, because many physical nodes reside in the same small area among a massive number of devices. Other nodes in low-diameter regions will exhibit the same overflow problem for unbounded node density or network scale. Nevertheless, the geohyperbolic addressing scheme overcomes these issues. It uses the local and purely geometric hyperbolic coordinates for routing in complex network topologies. Although node density cannot grow faster than polynomially on such networks, the average path length remains logarithmic for any realistic parameter configuration, allowing routing with a modest overhead. Solutions for cost-effective address space preparation include controllable geometric routing and hybrid addressing schemes. Simulation and experiment both show that with scale-, group-, and locality-invariant traffic patterns, the proposed schemes significantly outperform existing geographic and coordinate-based routing protocols, in terms of average routing path length, success rate and overhead, thus having the potential of broad impact. Guidelines for geo/topology-aware routing design in random graphs include local non-complex ways to measure network characteristics such as geographia, hyperbolicity, and cost/gain sets of paths; unbounded reachable sets in which ubiquitous packets can be sent elsewhere via simple routing schemes relaxed to local routing; and infrastructure/topology-centric approaches to Internet slices long before the emergence of content-centric networking. Such routing policies, based on scalable multicast and path stretching schemes, exploit measures and topologies on participation-based large-scale random networks, thereby addressing limitations in communication costs and scalability in state information.

IX. FUTURE TRENDS IN TELECOM NETWORKS

The roll out of fifth generation (5G) networks is a major milestone towards realizing the goal of a fully connected society. The vastly improved network capabilities on the technological side, especially the speed, reliability and flexibility provided by 5G, will trigger a wave of innovation both on the technological and business model side. Mobile cloud computing is providing adaptability and scalability for mobile devices over a diverse range of network connections. This integrated technology allows mobile devices cost efficient services for computing and storage for applications over the Internet [13].

Cloud-RAN functionality is fully emerging for partly centralized controlling of the radio resources with a cloud platform compatible with open interfaces built on standardized hardware platforms enhancing storage and processing ability. The coordination of the densely deployed small cells with multiple RAT co-existences is becoming a challenge which needs a high level of rapid computing and swiftly switching ability for handling all mobile devices. Telecom Operators, endowing wide spectrum and a dense network, are mudding the water. Although having submarine cables under their own trademark, Telecom Operators are in the fear of being the dumb pipes. The need of the telecommunication industry on networks becomes clearer: Stronger, seamless, simplified network mechanism while significantly saving cost.

To support new chunks of wireless communication in the conceptual design of the networks, the new concept of virtual network management and operation is proposed, which can be implemented by Network Function Virtualization and Software-Defined Networking looking into 5G telecom scenarios. Virtualization plays the role of abstraction and dynamic updates of the hardware level resources, and achieves functional unbinding which breaks the rigid coupling between network functions and hardware. SDN is the very centerpiece of NFV and can be viewed from two aspects. On the agility of the network resources, SDN enables adequate controlling of newly unbound network resources including bandwidth, configurability and routing thus can provide users excellent quality of service.

➤ *5G and Beyond*

5G is the fifth generation of mobile broadband networks. It is a technology that intends to improve the efficiency of current mobile networks by enhancing their robustness and lowering latency. Based on the 3rd Generation Partnership Project standardization, 5G accounts for different deployment scenarios and use cases. Standalone architectures include a new radio and core network capable of running without older technologies. Non-standalone architectures rely on the deployment of a new radio in conjunction with older generations of core networks. The new wireless technology frequency bands are designed to enhance mobile broadband user experience and allow ultra-

reliable low-latency communications, massive machine-type communications, and vehicle-to-everything communication based on geolocation and dense population. Core networks offer virtualization, allowing the isolation of time-sensitive and non-time-sensitive services in different sub-networks. With these properties, 5G and beyond are capable of enabling new applications that will change the way competition and businesses work. Network slicing allow, for instance, giving different sports events with different user experiences by mixing technology properties of core networks and wireless technologies [2].

5G and beyond present a good opportunity to diminish the digital divide. With open radio access networks, new vendors can design equipment compatible with interfaces defined by open software communities. Cloud provides many services that require minimal design skills and spending to deploy computer units in remote areas connected to the Internet. And there might still be many other hardware and software alternatives that require even less effort to build complex telecom networks. Consider, for example, CPUs of minimum cost but with an ability to run modern services able to simplify any telecommunication deployment. Unlicensed bands allow wireless communication on top of already existing Internet access technologies. Also, those devices can ease the design of next-generation mobile networks. For example, on the WiFi3, bandwidths of up to 160 MHz are supported using 8 channels of 20 MHz each. By using a coefficient of 16 on variables specified in the standard that control access to shared resources and improve the coexistence with other technologies, one can have a maximum usage of 300 Mbps per link with a cost below 10Dollars.

➤ *AI in Network Management*

The explosive growth of customer demand for broadband services in the past few decades has prompted telecom agencies to invest heavily in network development worldwide. The services offered by telecom networks have developed from the applications of voice and data in the early days to image, video and multi-media content in the present. As a consequence, fund managers of telecom initiatives are facing intense pressure to accommodate additional traffic at faster rates. The goal of network development plans is to reduce spend per bit, and better utilize the existing coverage. In addition to more passive system deployments, improved planning and optimization strategies are a key enabler to meet such objectives. Such an ecosystem run under the auspices of the telecom industry is envisaged to be the key enabling factor leading to the evolution of the control and optimisation operations of networks towards Telescopic Systems.

Telecom coverage is expanded by considering a wider range of potential solutions. In addition to investigating additional location points, radically different types of system arrangements are also considered. Numerous improved RF planners are published and implemented by telecom vendors

and consultants. However, their adoption by smaller sound engineering firms is slow due to software lock-in and high costs. Consequently, wider availability of better capacity estimation and TV white space simulation techniques will be investigated. One technology that has gained traction recently is LTE. Its advantageous propagation characteristics and large coverage radius have led to a dramatic increase in accumulation density in recent years. Proposed system placements have caught telecom planners' attention, who predict its inevitable adoption into future networks. The idea of using low-band technologies under high-frequency counterparts relies on reconciliation of TDD-LTE on Channel Info. In spite of numerous performance gains demonstrated, no existing acceptable solutions have been presented to facilitate practical feasibility, laissez-fair disturbance in the present architecture and several contentious questions regarding TC integration and its viability and robustness. There are several other measures which are able to improve the efficiency of existing systems. Long-range transmission can be achieved through a reduction of received data rate by trade-off with coverage. Dense networks at the cost of additional spending have been setup to reduce average loads on each station, which lowers congestion probability and thereby maximizes overall throughput. Efficient routing of failure recovery at earlier stages has been studied for fast problem identification and successful topology recovery. Nevertheless, these extensions have not considered intelligent recovery of congestion events, which occur frequently in networks of high throughput and hysteresis in software execution and in use case switch. Contemporary point-to-point routing implementations cannot include enough situations to guard where transmission drops due to usage intermissions and similar slab filtering supported by Global-Knob.

➤ *Edge Computing Integration*

The combination of intelligent routing and cloud-edge infrastructure provides the necessary computing and storage resource allocations for telecom providers. Intelligent routing takes advantage of the existing cloud-enabled infrastructure to use in-network-computing capability while retaining the routing decisions to the telecom provider. Compared with traditional approaches, this novel approach provides a much greater range of routing options and can accommodate more complicated allocation decisions such as dynamic resource monitors. If edge or local servers are already installed within the existing infrastructure, computer workloads can be deployed closer to clients. As more and more intelligent decisions are required by the telecom provider, more complicated computations will need to be offloaded from routers to the cloud. Therefore, it is important to enhance the edge conditions and optimization algorithms differently for different types of networks, be they local, edge, or cloud computing-enabled networks.

Edge computing is defined as the use of cloud computing capabilities in physically distributed IT resources. Edge computing also refers to architecture in

which the cloud computing capabilities are located physically closer to the data sources as compared to traditional architecture. Beyond a simple edge-to-core deployment, edge computing has many designs. For example, edge servers may run on a telecom broadband terminal in the form of virtual machines using containers or lightweight microservices rather than running on a series of dedicated servers. In such cases, where nodes are expected to be constrained, the refinement and optimization of the computation and allocation models would be required. Nonetheless, implementations using traditional edge servers is still a valid goal, especially for testing and justifying telecom providers' existing investment and infrastructure.

X. REGULATORY AND COMPLIANCE ISSUES

Telecom regulators throughout the world are faced with significant challenges caused by the rapid evolution of Next Generation Networks (NGN). Technological and market forces are driving operators and service providers to switch to next-generation network architectures based on Internet Protocol (IP). This change implies substantial changes throughout the value chain, and thus, significant challenges for regulators. In the core of the network, IP-based NGNs resolve long-standing interconnection disputes by changing debates over the apparently simple question of whether to build their own or interconnect, into more complex negotiations over terms for IP-based interconnection. This process has only begun; for VoIP services, interconnection is presently done primarily using PSTN gateways and relatively few VoIP peering arrangements, and other technically possible approaches to interconnection with differing implications for market structure would take longer to be deployed. While some guidance is beginning to emerge from discussions between telecoms and competition authorities, it is far from clear what policies will prevail in environments with competing operators. In a world with effectively no guards, interconnection would evolve via peer-to-peer arrangements resulting in more competition and the emergence of a whole new set of user-protected services. In contrast, transport monopolies might seek to impose payment terms on service providers through exclusive arrangements that would severely constrain infrastructure competition and innovation.

The access part of the telecom access network connects customers to the above mentioned core network. It is also in this portion that interoperability disputes will spill over from the Internet to the telecom arena. These disputes are fundamentally similar to those surrounding ISDN or DSL services. The last few 4 to 10 km involve fundamentally different technologies and architectures. However, both customers access one and the same core network. Separation of the core from the access would change the underlying economic issues. However, only limited dissemination of such architectures has yet occurred and transition to next generation access is generally slower than for the core. As regulators are being challenged to examine the significance

of this change both in terms of services and underlying technology, to draft appropriate responses in terms of deregulatory or regulatory action and to address issues of equal access, interconnection, and competition in a very rapidly evolving environment where many unique interdependencies exist. As a consequence, telecom regulatory authorities in Europe, Australia and Japan face unprecedented pressures. On one hand, they are falling behind the market and losing visibility and control over the scope of the NGA debates. On the other hand, the interdependencies between policy, core, access and interconnection are growing and further complicating the picture.

➤ *Telecom Regulations Overview*

In recent years, there has been considerable debate in many countries as to how to regulate next-generation networks (NGNs). Interconnection between telecom networks remains a basic principle of telecom regulation. Although the very characteristics of IP-based NGNs facilitate competition, because of the importance of interconnection to competition, it is also the most contentious regulatory issue globally. Interconnection can be viewed as the ability of one network operator to enable its customers to communicate with the customers of another network operator; access can be viewed as the use by one network operator of certain capabilities of another network operator as a component of the former's service. Other network operators' customer would see no harm once a given network operator enables essential access capabilities, such as the ability to carry traffic to/from a freely chosen destination. A range of additional regulatory issues have emerged, including access to emergency services, lawful intercept, and data retention issues. Under different regimes, some (but not all) of these issues are likely to raise less concern, whereas others will need to be considered further by regulators. Different countries have considered these issues, with the pace of regulatory proceedings conditioned by market evolution. Each country's approach has depended on a combination of two factors: the country's prior experiences with telecom regulation, especially those beyond access regulation; and the theoretical or ideological positions of regulators and political leadership. In the UK, British Telecom is replacing the PSTN core with an NGN core; in the Netherlands and Germany, incumbents are replacing parts of the traditional fixed access network with FTTC/VDSL-capable networks. In France, deployments of FTTB/H are occurring in major metropolitan areas served by France Telecommunications, a monopoly of the incumbent. In Japan, FTTB/H deployment has been successful with third-party involvement via NTT's agreement to lease dark fiber. In the US, concerns over innovation-stifling regulation have resulted in a hands-off light-touch regulatory approach to data services. Within the European Union, differences in regulatory approaches are likely to converge over time.

➤ *Compliance with Data Protection Laws*

Cloud providers dive into different developing technologies for big data, machine learning, web applications, etc. Many of them utilize a critical resource, Computational Resources Supply Chain (CRSC), to sustain their services. However, some operations of CRSC involve sensitive data. The security of CRSC and its operations should be taken seriously, particularly from legal compliance perspectives. In this work, a relevant legal framework, called the European GDPR, is introduced. Then its implications on CRSC operations are discussed. Particularly, it is analyzed how Personal Data (PD) should be considered by cloud providers in different contexts. Also, the case of cloud209 will be discussed as an example to help analyze the issues around legal compliance. Nowadays, a variety of activities including business transactions, social interactions, web searches, and knowledge discovery are organized into events. In a strict sense, an event is a piece of information outside an individual's observation and perception which can be sensed by him or her. One of the important aspects of an event is its spatio-temporal ranges. Geographic Regions of Events (GRE) and Time Intervals of Events (TIE) are both important aspects in determining what events are relevant to a user's request. Some real-world applications like knowledge-based services and recommendation systems require effective indexing and searching for events based on their GRE and TIE constraints. However, existing works mainly focus on deterministic range-based event representations and query models and seldom investigate on interval-based models.

XI. CONCLUSION

A study to determine how to expand the range that an operator's telecom network can cover was presented in this document. The data that was provided included some statistics about calls, their type, where they are located, and what sort of operator is providing the service. The location of the existing network was provided. It was found that an intelligent routing approach could better redirect these calls, allowing a wider area coverage using more massive increases in range. Various types of cloud-enabled infrastructure were examined, and it was determined that additional systems could increase range by shifting processing of calls. Cloud-enabled systems would facilitate this type of expansion. The analysis for each part of the information was included showing the calculations and logical steps that were taken. To close the report, there is also a section on limitations and possible future expansion of the landscape analysis.

One of the key factors in these conclusions is the possible loss of revenue by wireless companies attempting to expand their demographic coverage. These networks generally provide services to consumers in very defined geographical areas. As such, an expansion to a wider area, especially one close to that of another operator, would only be beneficial to the larger company. Therefore, some inquiry

into the size of a market and limit of growth in the old scenario should be made. Further justification for the necessary changes could be made: growing demand in smaller towns and outreach could change rates in greater benefits more than any population gains in suburbs. All these points are alluded to but not examined in detail.

The first recommendation is to investigate the costs and difficulties of entry into this type of market as another network operator, through acquisitions, or through a larger network of their own. The costs of providing access to physical networks can be very high, but the time and expenses of starting from scratch are worth examination. This alternative was offered briefly in the final simulation, but much more focus could be placed on this alternative way for network expansion into more rural smaller areas. There should also be consideration to extending the time frame: perhaps over the course of years, an operator may better budget an expansion of a network and costs involved. These investigations would greatly improve expanding of analysis and conclusions.

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