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The Future Carrier Network: Its Vision and Architecture

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SUMMARY We have been considering the architecture of the future carrier network which will be the successor to Next Generation Network (NGN). Our assessments have clarified the key problems that will arise in the era when NGN has matured. Based on our studies, we define the vision and the architecture that can solve these problems. This paper provides a snapshot of our work in order to contribute to research on the New Generation Network and beyond.

key words: *new generation network, carrier network, future internet, network services*

1. Introduction

The Internet has become the key infrastructure for social activities since it supports so many fundamental services. At the same time, several problems with the Internet have been noted like threats to social life and the costs of supporting the increase in traffic and users [1], [2]. Next Generation Network (NGN) is the first step to rebuilding the structure of the Internet and its service platform. In Japan, NGN service was introduced and its capabilities are being continuously enhanced [3].

This report assumes that NGN service will become mature around 2020 and addresses the infrastructure that will subsume NGN. To elucidate the future carrier network, we consider key problems in three areas: 1) services and applications, 2) implementation technologies, and 3) network operation and customer support.

By 2020 there will be a much broader variety of services and applications. For example, communication will range from very small sensor devices that send data once a month to super-high vision (8K resolution) systems that transmit at over 20 Gbps. The number of connected devices will explode since virtually every device will be provided with communication capability. These trends make the traffic continuously growing [4].

Can the physical layer infrastructure continue to keep pace with this growth in traffic? Up to now, transmission capacity has been increased by enhancing the optical transmission technology. How much bandwidth per fiber or optical channel will be available in the future? The answer is not so optimistic [5] since the rate of increase in transmission capacity is leveling off. Moreover, routers and switches require data processing power for intelligent traffic control as well as increasing their forwading capability. With regard to processor technology, single core clock speed has become saturated so multi core architectures appear to be the best way of increasing processor performance. Unfortunately, the number of cores in a single die may be limited, so we are not optimistic about significant enhancements in processor technology. Moreover, environmental concerns are imposing tight constraints on technologies, particularly with regard to power consumption. This renders unacceptable the approach of over provisioning the network. Network resources such as bandwidth or physical paths must be adaptively assigned to services according to actual demands and/or usage.

Network operation is another concern of the future carrier network. The network must support more applications so network operation should have more functions to manage the various applications. Several services will be integrated in a single system which requires even more complicated operation functionality. There exists the possibility that the scalability of operation functions will become the bottleneck hindering the enhancement of network services. Due to the penetration of the Internet, the social impact of networking services is extremely large. Most of the transactions essential to personal life are handled or will be handled by services in the Internet. You must provide more data about yourself if you are to increase the benefit received from network services, but this increases the threat of your information leaking to anonymous people.

Our goal is to elucidate the future carrier network and its architecture based on our assessment of the potential problems faced by the network. In the following sections, we propose the vision of our future network based on our findings in Sect. 2. An outline of the architecture that realizes our vision is described in Sect. 3. We conclude the discussion in Sect. 4.

2. Vision

2.1 Network Design Requirements

In the future carrier network, breakthrough technologies are anticipated to solve the below requirements.

Requirement 1 wide variety of user demands
Requirement 2 efficient resource utilization
Requirement 3 secure and operational platform

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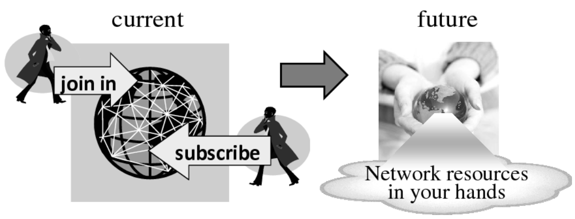

Fig. 1 Network design philosophy change.

In the current network, people access the service network by joining/subscribing to the existing network or network services. If everyone has very similar usage patterns and there are few patterns (video, voice and data), this type of network design offers maximal efficiency because all usage patterns can be provisioned easily. Our Requirement 1 indicates that we must change of our view of network design. There will be so many usage patterns that it will not be feasible to set a limited number of patterns. Network design will need to meet individual user demands.

Here, we depict the change of design philosophy in the future carrier network in Fig. 1. In the current network, users or facilities are connected to the existing network where the usage patterns are assumed to be known and no interactions are provided between network and users. The future carrier network will be a sort of resource pool and a user or a group of users will create their own network by selecting the resources needed from this pool. Not only network resources but also computing resources like processing resources, storage resources, and other facilities used for providing services are considered in the resource assignment process.

Requirement 2 requires a global optimal solution for assigning network resources to the various user requests. When a resource is selected, resource assignment will be managed by resource providers who must consider all user requirements and try to achieve optimal assignment according to the changes in user behavior or usage patterns. Thus the action of selecting resources from a pool provides the interaction between user and network in order to achieve the optimal resource usage.

How is Requirement 3 to be reflected in a new design philosophy? Security concerns will be resolved by some part of the resource assignment policy. The user will organize his trusted resources and connections and know the risks posed by the resources.

2.2 Service Categories and Their Security Properties

Various services will be provided in the future carrier network. We need service categorization in order to clarify the service variation. This will allow us to consider a method of tailoring the network design in each category. In Fig. 2, we depict the relationship between the number of connected terminals and the required communication bandwidth. We set three major service categories: Tiny-band Mass Service (TMS), Broadband packet service (BPS), and Huge band service (HBS).

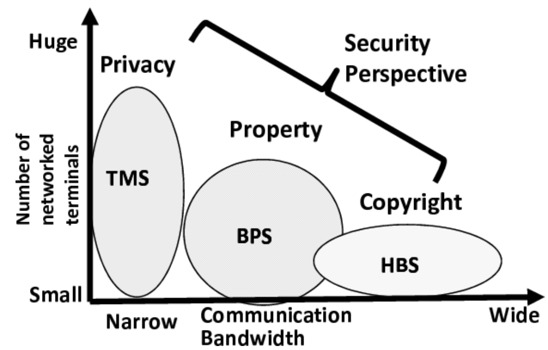

Fig. 2 Service and security categories.

The category of TMS includes, as typical examples, sensor networks and inter-device communication. Each terminal has very narrow bandwidth requirements or communicates very infrequently; however, the number of connected terminals will be huge. A TMS based service like the sensor network will tend to handle personal related data. This requires that data privacy be kept during communication.

BPS covers future packet-based services. Even in 2020, IP based services may be dominant and other packetized services will be deployed to support various data communication needs. To handle the communication related to the social needs and business transactions, the security of various properties is of course essential.

An example of HBS is an end-to-end optical connection carrying Super High Vision streaming from the ball park to a theater for public viewing or multi point communication for establishing a shared environment for remote parties. In data transmission, the services include data backup and communications among Grid resources or Cloud computing resources. HBS is related to copyright protection in terms of security since the contents exchanged over the network will be extremely valuable.

In the future carrier network, both the performance needed to support the required service and the security perspective are important attributes for designing the network. Both of them are to be considered simultaneously in designing the network architecture.

3. Architecture

Based on the service visions discussed in the previous section, this section deduces properties of the architecture of the future carrier network. We then try to design the architecture of the future carrier network.

3.1 Requirements

In the service vision, there are two important points that impact the design of the architecture as follows.

1. Flexibility for customer connections and the network should be an resource pool for ICT functions.
2. At the same time, the two orthogonal requirements of

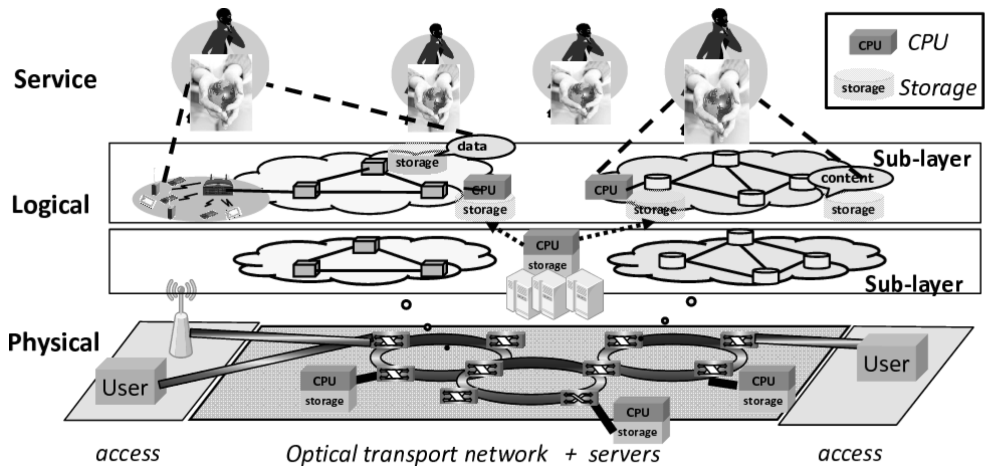

Fig. 3 Architecture of the future carrier network.

"isolating" each service but "sharing" (physical) resources are imposed.

Considering the service category, HBS requires a dedicated fat pipe that is also highly isolated for copyright protection. For BPS, a more flexible network configuration will be needed with flexible packet forwarding. Intelligent control may be achieved by referring to the deep properties of each packet. For TMS, the communication type is like a logging system event or a database access transaction. The typical service will gather atomic data and apply post-processing to extract the desired data for further processing. The anonymity of communication is important to ensure security because the source of the data is an indicator of personal information or may even specify a person.

3.2 Architecture Design

Figure 3 depicts the proposed architecture of the future carrier network. This architecture defines three layers: Physical, Logical and Service.

The Physical layer consists of optical transport network, computational resources, and wireless/optical access network. The physical layer provides the flexibility needed to form isolated networks.

We define two sub-layers in the Logical layer. One is related to the Physical layer and the other is related to the Service layer. The service related sub-layer is mapped to the physical related sub-layer when a service is deployed. Why are two sub-layers required? This approach makes service design independent of the physical layer. Together they define the topology that suits the service architecture. On the other hand, the physical layer flexibility will allow several physical resource combinations to realize the same logical topology defined by the service layer. To ensure design freedom for both sides, we separate the two sub-layers. One is mapped to the other in an appropriate manner as described below. There are two mapping approaches. After getting the service side topology, physical resources are gathered and organized to suit the service topology. This enables the most effective or most suitable physical resource combination to be chosen. For HBS, dedicated optical paths are used among connections and this is very secure because they are completely isolated and have enough bandwidth. On the other hand, like the IP network, a well-designed physical network is provided and several different service networks are mapped on to the one physical related sub-layer. This enables maximal resource sharing in the physical layer by different logical services. This flexible mapping is quite different from the current network layering scheme which mostly provides a single structure for both service related and physical related sub-layers with no freedom to select from among several network designs. The proposed architecture provides flexible mapping between physical related and service related sub-layers. Notice that sub-layer designs can be created according to the demand.

With regard to the security issues, the extremely variable communication streams are protected by optical paths in the physical layer in HBS. This is highly secure because specific streams are isolated from other traffic. For BPS, the packets are not fully isolated by the communication path since they are shared by several different services thus a virtual isolation function is required. The flow-based router [6] or openflow [7] is a typical example of the virtual isolation function for the IP network. In this method, a service associated flow is specified by analyzing the packet then each flow is handled independently. To ensure privacy in TMS, the physical layer tends to retain private information. This can be achieved by mapping a service-sub layer to a physical-sub layer in an anonymous way.

3.3 Access Network

The access network should also support the various end points and the various usages expected. To provide accessibility to users, wireless access will be dominant in the last part of the access network.

When increasing the number of subscribers and the number of base stations for wireless access, a critical problem is where the access lines should be terminated and connected to the backbone network. For wireless access, there are several protocols according to the terminal requirements like bandwidth, power consumption, and diversity. Terminating wireless protocols in the base station means that all functions of the supported wireless protocols must be implemented in each base station. This makes the cost of owning a base station very high. To reduce the cost, the flexible termination of wireless protocols can be realized through the ROF (Radio on Fiber) technology [8]. This conveys the wireless signal over fiber to the terminated point. If the same protocol signals are conveyed to the same termination point, we can share the processing resources. To extend this idea, if wireless signals can be transferred to any point, we can freely choose the appropriate termination points according to the traffic volume and/or network status. This will yield flexible resource assignment in the access network.

3.4 Operation

The operation system of the future carrier network is very important because the infrastructure itself never solves all problems or meets all requirements of the future carrier network. The proposed future carrier network demands two major capabilities in its operation system as follows:

1. it should be scalable to network size and the variety of network systems,
2. it should be easily developed in network management.

There are many functions in an operation system. Here, we focus on the functions needed to support customers and trouble shooting. When a user inquires about service usage or trouble, the operator always asks "when, what, and how are you using?." These pieces of information are necessary to analyze the user's situation. This process is not so easy because often the customer does not know or can not describe his situation well so the operator side must guess the situation using experience. Since there will be many different services in the future, it is impractical to rely upon the experience of the operator to analyze the situation. To understand the user's situation, the future carrier network must include a traffic monitoring function that can recognize the user behavior as "context." Intelligent control and support is provided according to user context. This approach will be very helpful in resolving user complaints. Moreover, through continuous monitoring, pro-active control can be applied to avoid user troubles. Observation will make network service operation more mature.

4. Conclusion

In this paper, the vision and architecture concept of the future carrier network were discussed. In our vision, network service is created through the interaction between service and network and security is an important requirement. In the architecture, the flexibility of resource combination is fully utilized by service demand considering the efficient resource usage of the entire network.

There are two important research directions in the next step. One is to clarify the essential problems and create formal definitions of the problems. Based on this analysis, the other is to evaluate and improve the proposed concepts through prototype experiments on testbeds. The creation of future network testbeds is the most important activity to accelerate these research activities and clarify the essential problems of achieving the innovative society of the future.

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