# All about the user with ADN

For network construction, application-driven networking (ADN) provides logically independent network slices to meet the varied networking requirements of different applications. When it comes to the conflict between service differentiation and network neutrality, ADN is the peacemaker.

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## Challenges in future networks

### 1. Operator revenue depends on user base size, but user growth has bottlenecked

The Internet's network architecture was designed with data traffic in mind, not the unique requirements of different applications. As this architecture still dominates, operator revenues rely heavily on subscriber numbers and data traffic volume. Professor Srikant from the University of Illinois makes this exact point by referencing current Internet price plans in Economics of Network Pricing with

Multiple ISPs, including the popular flat rate with cap, smart data pricing, sponsored data plans, and older per-use or monthly quota plans.

With the recent plateauing of subscriber growth and cost jumps for operators, operators are feeling huge pressure from stagnant data revenues coupled with a sharp increase in data traffic.

### 2. Net neutrality rules restrict service differentiation

Net neutrality was initially proposed as a way of protecting new companies and applications by preventing certain content providers from monopolizing the market, because operators cannot differentiate between different service sources. However, with networks unable to deliver the low latency and high bandwidth required by services like HD video, content providers are constructing their own networks, and in effect strangling operator revenues.

In *A Two-Sided Market Analysis of Provider Investment Incentives with an Application to the Net-Neutrality Issue*, California University lecturer John Musacchio et. al. sets out the idea of the "two-sided market". The paper proposes how net neutrality is not in the public interest in some situations, and can cause the "tragedy of the commons" effect where individual users deplete a resource by acting in their own interest rather than that of the common good.

Professor Vishal Misra of Columbia University introduced the idea of the Public Option ISP to eliminate selective discrimination against content providers during market competition and reduce regulatory costs. Whether it's possible to maintain net neutrality in line with the original spirit of the idea is open for debate given existing network architecture.

## Distinct network architectures for different applications

In the era of voice communication, the principal consumer unit was a single person and the basic requirement of telecom networks was person-to-person voice communication. Networks also provided a small amount of data communications, such as telegraphs, alongside this single service.

When it came to network growth, the chief barriers were improving coverage and lowering costs. Research shows that in a voice network, the subscriber call arrival process closely follows the Poisson distribution model, meaning statistically active subscriber numbers remain at a mean value over time, making statistical multiplexing possible.

As a result, hierarchical aggregation became the basic telecom network architecture, which became operators' guiding principle for network construction for many years, encompassing the point of access to the MAN to the backbone. This was able to fully meet subscriber requirements and reduce network construction and management costs.

In the Internet era, there's been a dramatic shift in user network consumption patterns. This has presented a considerable challenge to existing telecom networks that are built on hierarchical aggregation architecture. While Internet user requirements include person-to-person communication, humans-to-things communication occurs in greater numbers, for example, with machines or datacenters. Communication length and bandwidth requirements have increased and become less determinable in this era.

In *Emergence of Scaling in Random Networks*, which appeared in Science magazine in 1999, Barabasi and Albert point out that Internet applications comply with the features of a scale-free network, also known as a "power law distribution" network. In this type of network, most users are connected to super nodes like Google or Facebook. Most nodes are connected to just a few super nodes, making this type of network fundamentally different to a Poisson distribution voice network.

In *The Flattening Internet Topology: Natural Evolution, Unsightly Barnacles or Contrived Collapse?* Professor Li Zongpeng from Calgary University states how network flattening is inevitable in the Internet era, because flat network architecture is better suited to a power law distribution network and is more resource efficient. Thus, network flattening has become a guiding principle of network construction in the Internet era.

New services like the Internet of Things (IoT), Internet of Vehicles (IoV) and virtual reality (VR), will inevitably impact future network architecture. In collaboration with Professor John Lui of the Chinese University of Hong Kong and Professor Chen Guanrong of Hong Kong City University, Huawei's Future Network Theory Lab released a paper proposing the entirely new Markov Model of processes. The paper points out how the characteristics of future network services will differ significantly from both the Poisson distribution model for voice networks and the Internet-oriented power law distribution model.

In the future, network services will comply with the Markov Process model of process distribution whereby applications will demonstrate diverse dynamic conversion over time, causing greater differentiation in the application requirements of different sectors and services such as IoT apps or HD video.

A processing approach where optimal resource efficiency is concentrated in central nodes doesn't suit applications such as IoV, which requires low latency vehicle-to-vehicle communication in a partial automation scenario. Current network architecture will also have difficulty meeting the requirements for high bandwidth, low latency, and high reliability of a service such as telemedicine. A new application-driven network architecture is therefore necessary to optimize customer experience.

## ADN: A role model for differentiated services

Most players in the telecom industry want to improve resource efficiency, especially network hardware, which reduces costs but doesn't increase revenues. But, ADN equally prioritizes application efficiency and resource efficiency because improving application efficiency makes applications easier to use, which in turn improves user experience and increases revenue.

ADN advocates application-led network construction. The ADN solution gives each application a logically separate network to meet the distinct demands of different applications. ADN helps operators achieve application-oriented network reconfiguration, resource virtualization, and hierarchical control.

**Application-oriented network reconfiguration: Abstracting application network requirements.** ADN builds multi-dimensional abstract models of applications by analyzing network requirements and their usage features to orchestrate network resources and meet application requirements. To improve user satisfaction, different services can be mapped to different network resources using models like Poisson distribution person-to-person communications services, power law human-to-machine communications services, and Markov process distribution machine-to-machine communication.

**Application-oriented resource virtualization: network resource isolation and re-use.** NFV and network slicing make it possible to abstract originally unified, unique network resources – such as wireless air interfaces, bandwidth, computing power, and storage space – into multiple logic channels. Then, ADN performs statistical multiplexing on network resources to comply with applications' networks requirements.

**Application-oriented hierarchical control: fast neural/slow neural control.** ADN provides differentiated services for applications and optimizes network resources.

**Application-oriented hierarchical control: fast neural/slow neural control.** ADN provides differentiated services for applications and optimizes network resources. According to the concept of fast and slow neural control proposed by California Institute of Technology professor John C. Doyle, ADN performs fast and slow control on network resources in multiple dimensions, including time, space, and value. The slow controller regards slow-changing network information – such as network topology and application service model characteristics – as input, and finds network resource slice division methods and network optimal control points. The fast controller uses network fast-changing information like switch queues and link status to carry out real-time observations. It uses Kalman filter algorithms to drive the network to the optimal control points on different slices at the lowest cost. In cooperation, fast and slow control mechanisms can ensure the whole network operates near an optimum control point, helping optimize application-oriented services.

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## Focusing on customer experience

***The ADN concept identifies application service characteristics and allocates appropriate resources accordingly.***

The biggest transformation that ADN brings over standard communication networks is vertical resource distribution on a per application basis. The architecture for standard communications network is horizontal and layered according to resources with a resource layer, control layer, and application layer at the top. ADN streamlines multiple vertical layers for different applications top-down from the application layer to the control layer to the resource layer, improving user experience by switching from a horizontal to a vertical framework.

Traditional network resource management normally groups network resources by network layer, for example, by access network, MAN, or backbone network. This can maximize resource utilization, but it isn't optimal for application experience because a typical application might be spread across multiple network elements, making launching and modifying an application extremely complicated. In normal circumstances, applications must be modified to adapt to the network for a good user experience.

The ADN concept identifies application service characteristics and allocates appropriate resources accordingly, executing service management on applications, and enabling the network to proactively adapt to them. In multi-application scenarios, the successful application of ADN architecture will hinge on how resources are allocated, the principles they're allocated on, and on balancing the allocation of existing resources and possible future applications.

The system performance of different service traffic models like latency and throughput is significantly influenced by scheduling and resource allocation policies. In *Scheduling in Switched Queuing Networks with Heavy-Tailed Traffic, MIT's Dr. Mihalis G Markaksi* states that unlike services that comply with Poisson arrival characteristics, service types with heavy-tailed distribution adopt multi-queue load balancing scheduling policies, which greatly ramps up performance. Therefore, for system expansion, scale-out policies rather than scale-up policies are preferred.

The Poisson distribution model of voice, the power law distribution model of the Internet, and the Markov process distribution of future networks form the theoretical basis of ADN resource allocation.

ADN architecture incorporates application-oriented resource allocation mechanisms. There are a number of dedicated resource allocation layers: hierarchical network connectivity based on Poisson distribution rules for voice applications; flattened networks based on power law distribution for allocating Internet resources to data centers; and, for IoV applications, autonomous networks based on Markov distribution rules to meet low latency requirements and centralized resource allocation to satisfy massively concurrent applications.

Key resources are reserved to meet the different requirements of future applications based on service development forecasts.

In an ADN framework, cloud technology can support ADN resource allocation. SDN and NFV can support many kinds of applications on a single network by ensuring technological capabilities. Ultra-broadband Internet ensures that resource allocation and scheduling are more flexible and convenient, while the ADN framework uses current technology to enhance user experience. Service diversification and user experience will be typical features of 5G networks, both of which ADN will support.

## Dual focus on application and resource efficiency

Early communication networks and that era's Internet focused on voice and high traffic volume and low-cost data services. Network construction and development aimed to raise efficiency and bandwidth under a single service-oriented model that prioritized resource efficiency.

But, future networks will be characterized by a diversity of applications and highly varied requirements on network resources. For example, the resource requirements of two key future applications, HD video and IoT, differ greatly, meaning that a blind focus on resource efficiency cannot meet varied user experience requirements. Application-driven network construction will therefore be common in future networks.

## ADN: Good for construction, good for users

ADN optimizes configurations based on different application types when total resources are constant, meeting varied application requirements and driving up user experience. Two real-world examples of heterogeneous application requirements unsupported by current networks are as follows:

IoT applications for automated meter-reading: requires a large number of user terminals and high bandwidth, has high requirements on the control channel, and is highly cost-prohibitive.

Instant messaging applications: creates signalling storms where bandwidth consumption is low but continually refreshes to stay connected, for example, WeChat.

In the first example, network slicing offers a solution. In the second, reserving a certain amount of signalling resources can solve the signalling issue.

ADN provides a framework that supports both these methods.

## Resource efficiency through application efficiency

ADN meets requirements for application efficiency to improve user experience without compromising resource efficiency, using tech like SDN and NFV to boost application efficiency.

ADN can also use NUM (network utility maximization) for organic decoupling and to collectively upgrade application efficiency and resource efficiency, which can reduce network construction costs, increase operational efficiency, and generate revenue from applications.

Application efficiency and resource efficiency will inevitably become mutually complementary, as indicated by the computing industry. The first computers to emerge were specialist computing tools with limited capacity and performance, causing the focus to shift to increasing CPU efficiency. The assembly language of computer programs precisely controls each specific physical resource of the CPU. With higher CPU capabilities and the more advanced C programming language, ease of use and application efficiency improve at the expense of resource efficiency.

With hardware continuing to advance in line with Moore's Law, the emergence of operating systems represented a fundamental breakthrough in computer applications. Increases in application efficiency hugely expanded the market, giving rise to what would become the world's largest industry. Switching from a focus on resource efficiency to a dual focus on application and resource efficiency grows the market, and encourages less priority on resource efficiency.

## The time is now for application-led network construction

Most operators already realize that networks should be application focused, and network slices are a trial foray into this space. ADN's major benefit is giving operators the network architecture to support diverse applications and grow beyond the current resource efficiency service model that focuses on traffic and bandwidth. They will open the door to the multi-service application era where application experience is also key.

PARC's GUI allowed computers to meet consumer usage requirements, spawning an entirely new industry and making the likes of Apple and Microsoft possible today. In the same way, we believe that the ADN concept and architecture will help operators support the myriad IoT services of the future, forming a virtuous cycle between application efficiency and resource efficiency, and pushing us towards operating models based on user experience.

An operating model based on customer experience has universal value – it can guide the development of future telecoms networks, and create growth opportunities for new services in storage, computing, and the entire ICT market. Similarly, it will be possible to extend the concept of ADN to create application-driven storage (ADS), application-driven computing (ADC) and application driven ICT (ADICT). "Application" here can be understood in the conventional sense, but also as an industry application. It can apply to new applications that have not yet been invented, and so the growth potential is nothing short of massive.