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CS642

Next Generation Networks

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CS642

Next Generation Networks

Lecture Handouts

Prepared for the students of Virtual University of Pakistan

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1. Evolution Toward NGN

LEARNING OBJECTIVES

- Define Next Generation Networks
- Trace evolution from PSTN to NGN
- Explain the drivers of convergence

The ITU-T defines a **Next Generation Network (NGN)** as a packet-based network able to provide telecommunication services, making use of multiple broadband, QoS-enabled transport technologies, in which service-related functions are independent of underlying transport technologies. In short: one converged IP-based network carrying voice, video and data - replacing the separate PSTN (voice), X.25/Frame Relay (data) and broadcast (video) networks of the past.

Evolution path: **PSTN** (circuit-switched, 64 kbps channels, intelligent network services) -> **ISDN** -> **ATM** (cell-based, first QoS-aware multiservice attempt) -> **IP/MPLS backbones** with VoIP overlays -> **NGN** (separation of transport, control and services) -> **5G/IMS** and cloud-native cores. Drivers: falling voice revenues, exploding data/video demand, the cost of maintaining parallel networks, and the flexibility of IP - one network to build, one to operate, any service to deploy.

Convergence

The merging of voice, data and video onto a single packet-switched infrastructure, and of fixed and mobile access (FMC) under common control.

SECTION SUMMARY

NGN = packet-based, QoS-enabled, service/transport-separated converged network. Born from the economics of replacing many single-service networks with one multiservice IP core.

2. NGN Architecture and Principles

LEARNING OBJECTIVES

- Describe the NGN layered architecture
- Explain separation of services from transport
- Identify key functional planes

The NGN reference model has four strata: (1) **Transport stratum** - access networks (xDSL, FTTH, WiMAX, LTE) plus the IP/MPLS core; (2) **Control stratum** - call/session control (softswitch, CSCF in IMS); (3) **Service stratum** - application servers (voicemail, IPTV, presence); (4) **Management plane** - OSS/BSS, security, QoS policy. **Open interfaces** between strata let operators mix vendors and launch services without touching transport.

Core principles: **packet-based transfer** (IP); **separation of control functions** among bearer, session/call and application; **decoupling of service provision from network** (third parties can offer services via APIs like Parlay/OSA); **support for multiple last-mile technologies; end-to-end QoS**; interworking with legacy networks via gateways; and generalized mobility. This is the 'hourglass' model: everything converges on IP at the waist.

- Bearer vs control vs service: media flows through gateways; signaling through softswitches; logic in application servers.
- Result: a new IPTV service needs only a new application server - not a new network.

SECTION SUMMARY

NGN's power is architectural: layered strata with open interfaces decouple services from transport, enabling multi-vendor, multi-access, rapidly innovated networks.

3. Softswitch and Media Gateways

LEARNING OBJECTIVES

- Explain the softswitch concept
- Describe media, signaling and trunk gateways
- Explain MEGACO/H.248 and SIGTRAN

The **softswitch** (call agent/media gateway controller) is the NGN's telephone exchange in software: it handles call control, routing, billing and service logic, while dumb **media gateways** convert media streams. Decomposing the monolithic Class-5 switch into software control + commodity media hardware slashed costs and enabled rapid feature development.

Gateway types: **trunking gateways** (PSTN <-> IP, TDM voice to RTP); **access/residential gateways** (analog phones to IP); **signaling gateways** (SS7 <-> SIGTRAN). Control protocols: **MEGACO/H.248** (master-slave: softswitch commands gateway to create/modify media connections); **SIGTRAN** suite (M2UA/M3UA) transports SS7 over IP so softswitches interwork with legacy signaling; **SIP** is used between softswitches and toward IMS.

SECTION SUMMARY

Softswitch = centralized call intelligence; gateways = distributed media conversion. H.248 controls gateways, SIGTRAN carries SS7 over IP, enabling graceful PSTN interworking.

4. IP Multimedia Subsystem (IMS)

LEARNING OBJECTIVES

- Describe IMS architecture and its CSCF nodes
- Explain SIP-based session control
- State IMS services and its role in 4G/5G

IMS (3GPP/ETSI TISPA) is the standardized NGN control architecture for multimedia: an all-IP core where **SIP** (Session Initiation Protocol) sets up voice, video and messaging sessions. Key nodes: **P-CSCF** (proxy - first contact, in visited network), **I-CSCF** (interrogating - locates the S-CSCF), **S-CSCF** (serving - registration, session control, triggers application servers), **HSS** (subscriber database, evolved HLR), **MGCF/MGW** (PSTN breakout) and **application servers** (telephony AS, presence, IPTV).

IMS made **VoLTE** possible: voice as just another SIP/IMS data service over LTE with QoS bearers (QCI=1). Services: HD voice/video calling, RCS messaging, presence, push-to-talk, IPTV. In 5G, the Service-Based Architecture extends IMS principles - network functions as HTTP/2 services. Pakistan's operators launched VoLTE on IMS cores in the late 2010s.

SIP

Session Initiation Protocol - text-based signaling (like HTTP) for creating, modifying and terminating multimedia sessions; the signaling heart of IMS and VoIP.

SECTION SUMMARY

IMS = SIP-based, CSCF-structured control layer delivering all multimedia services (VoLTE, RCS, IPTV) over any IP access - the control plane of 4G and the ancestor of 5G's service-based core.

5. MPLS in the NGN Core**LEARNING OBJECTIVES**

- Explain MPLS labels and LSPs
- Describe MPLS VPNs and traffic engineering
- Explain MPLS role in QoS

MPLS (Multi-Protocol Label Switching) forwards packets by short fixed-length **labels** rather than longest-prefix IP lookup: an ingress LER pushes a label, core LSRs swap it, egress pops it - the **Label Switched Path (LSP)**. Labels enable **traffic engineering** (explicit routes avoiding congestion, via RSVP-TE) and **VPNs** (labels + VRF tables isolate customer routing - L3VPNs per RFC 4364).

In NGN cores, MPLS provides the QoS-aware transport: the 3-bit **EXP/TC field** maps to DiffServ classes, so voice packets get priority end-to-end; **fast reroute** (FRR) restores failed LSPs in ~50 ms, matching SONET/SDH resilience that carriers demanded. MPLS-TP extends this to

packet-transport networks. Segment Routing (SR-MPLS) is the modern simplification, encoding paths as label stacks without per-flow signaling.

SECTION SUMMARY

MPLS gives the NGN core traffic engineering, VPN isolation, sub-50ms protection and DiffServ-mapped QoS - carrier-grade behavior on packet infrastructure.

6. Quality of Service in NGN

LEARNING OBJECTIVES

- Define QoS parameters
- Compare IntServ and DiffServ
- Explain QoS mechanisms and SLAs

QoS parameters: **bandwidth**, **delay** (ITU-T G.114: <150 ms one-way for voice), **jitter** (delay variation; <30 ms for voice) and **loss** (<1% for voice). Mechanisms: classification and marking, **policing/shaping** at edges, **queuing** (priority queuing, WFQ - weighted fair queuing), and admission control.

IntServ/RSVP reserves resources per flow - precise but unscalable in cores. **DiffServ** marks the 6-bit **DSCP** field and applies **per-hop behaviors** (EF - expedited forwarding for voice, AF - assured forwarding classes, BE - best effort) - scalable, the NGN choice. End-to-end QoS needs consistent marking across domains, enforced by **SLAs** between operators. Voice/video get EF; signaling AF; bulk data BE.

■ VERY IMPORTANT

G.114 numbers are exam favorites: one-way delay under 150 ms (good), 150-400 ms (acceptable), over 400 ms (unacceptable) for conversational voice. Jitter buffers trade delay for smoothness.

SECTION SUMMARY

QoS = managing delay, jitter, loss via DiffServ marking (EF/AF/BE), smart queuing and SLAs - IntServ's per-flow precision sacrificed for DiffServ's core scalability.

7. VoIP Signaling: SIP and H.323

LEARNING OBJECTIVES

- Compare SIP and H.323
- Describe SIP call flow
- Explain NAT traversal issues

H.323 (ITU-T) was the first VoIP standard - comprehensive but complex (H.225 call signaling, H.245 capability exchange, RAS gatekeeper). **SIP** (IETF RFC 3261) won with HTTP-like simplicity: INVITE/ACK/BYE methods, URIs (sip:user@domain), proxy/registrar servers. A basic call: INVITE -> 180 Ringing -> 200 OK -> ACK; media then flows directly peer-to-peer via **RTP/RTCP** (SDP negotiates codecs/ports).

Codecs: **G.711** (64 kbps PCM, toll quality), **G.729** (8 kbps, near-toll), **Opus** (adaptive, modern). **NAT traversal** is VoIP's classic headache - solved by STUN (discover public address), TURN (relay when symmetric NAT) and ICE (try all candidates). Session Border Controllers (SBCs) at operator edges handle NAT, security and transcoding.

SECTION SUMMARY

SIP's text-based simplicity beat H.323's complexity. RTP carries media, SDP negotiates it, and STUN/TURN/ICE plus SBCs tame NAT - the practical VoIP stack.

8. Fixed-Mobile Convergence and Access Networks

LEARNING OBJECTIVES

- Explain FMC concepts
- Survey NGN access technologies
- Describe the role of IPv6

Fixed-Mobile Convergence (FMC): one subscriber identity, one bill, seamless handover between fixed (DSL/fiber/WiFi) and mobile access - e.g. calls that start on home WiFi (VoWiFi) and continue on LTE. Enablers: IMS as common control, UMA/GAN for WiFi-cellular handover, and single-number services.

Access evolution: **xDSL** (ADSL/VDSL over copper), **GPON/FTTH** (2.5 Gbps shared passive optical - the endgame access), **DOCSIS** over cable, **WiMAX** (early 4G attempt), **LTE/5G** wireless. **IPv6** is NGN's addressing foundation - 128-bit space ends NAT dependence, restores end-to-end reachability for peer services, and is mandatory in 3GPP IMS/5G cores (Pakistan's operators run dual-stack transitions).

SECTION SUMMARY

FMC unifies fixed and mobile under IMS control; fiber (GPON) and LTE/5G are the access endgame; IPv6's vast space underpins end-to-end NGN services.

9. NGN Security**LEARNING OBJECTIVES**

- Identify NGN threat categories
- Describe security mechanisms per stratum
- Explain lawful interception and identity

Threats multiply when telephony meets the Internet: **DoS** on softswitches/SBCs, **SIP spoofing/SPIT** (spam over IP telephony), eavesdropping on unencrypted RTP, toll fraud, and attacks on management interfaces. NGN security is stratified: transport (IPsec, firewalls, SBC topology hiding), control (TLS for SIP, AKA authentication via HSS), services (application authentication) and management (hardened OSS access).

Mechanisms: **IMS AKA** (mutual authentication using SIM credentials), **IPsec** SAs between UE and P-CSCF, **TLS** for SIP signaling, **SRTP** for media encryption, and **SBCs** as security borders (DoS protection, malformed-packet filtering). **Lawful interception** is architecturally built in (X1/X2/X3 interfaces) - a regulatory requirement for operators in Pakistan under PTA rules.

SECTION SUMMARY

NGN security layers IPsec/TLS/SRTP, IMS-AKA authentication and SBC border protection over every stratum - with lawful interception as a built-in regulatory function.

10. SDN, NFV and the 5G Core**LEARNING OBJECTIVES**

- Explain SDN and NFV concepts
- Describe the 5G service-based core
- Relate to NGN evolution

SDN separates the control plane from forwarding - a central controller programs switches via OpenFlow/NETCONF - enabling flexible traffic engineering. **NFV** virtualizes network functions (firewalls, SBCs, even the mobile core) as software on commodity servers, orchestrated by MANO. Together they make the network itself software-defined and cloud-deployable.

The **5G core** is NGN principles taken to the limit: a **Service-Based Architecture** where network functions (AMF, SMF, UPF, PCF...) expose RESTful HTTP/2 APIs; **network slicing** carves virtual end-to-end networks (eMBB, URLLC, mMTC slices) from one physical infrastructure; control/user-plane separation (CUPS) puts UPFs at the edge for low latency. Pakistan's 5G trials and PTA's framework process follow this global architecture.

Network slicing

Creating multiple isolated virtual networks with different QoS/characteristics on shared physical infrastructure - e.g. a URLLC slice for autonomous vehicles alongside an mMTC slice for sensors.

SECTION SUMMARY

SDN/NFV softwareize the network; 5G's service-based core and slicing are NGN's logical conclusion - fully virtualized, API-driven, multi-service infrastructure.

11. IPTV, Multimedia Services and Numbering

LEARNING OBJECTIVES

- Describe IPTV architecture
- Explain ENUM and number portability
- List NGN multimedia services

IPTV delivers TV over managed IP networks with QoS (unlike best-effort OTT): architecture has head-end (encoders), middleware, VOD servers, and multicast for live channels (IGMP/PIM) - one stream serving thousands. **IMS-based IPTV** (TISPAN) integrates TV with telephony/presence - click-to-call from the TV screen.

ENUM maps E.164 phone numbers to SIP URIs via DNS (e.g. 4.3.2.1.5.5.5.e164.arpa), bridging numbering worlds. **Mobile number portability** databases and **number translation** services live in the control stratum. Multimedia services on NGN: HD voice/video, RCS, push-to-talk over cellular (PoC), multiparty conferencing (MRF media resource function), and converged messaging.

SECTION SUMMARY

IPTV shows NGN's QoS-managed multimedia; ENUM bridges phone numbers to SIP; the service stratum hosts the converged applications users actually see.

12. Exam Pointers

High-yield topics

- ITU-T NGN definition verbatim; the four strata; separation of service from transport.
- Softswitch vs gateway split; H.248/MEGACO, SIGTRAN, SIP roles.
- IMS nodes: P/I/S-CSCF, HSS, MGCF, AS - and VoLTE as the flagship service.
- MPLS: label, LSP, LER/LSR, VPNs, TE, FRR, EXP->DiffServ mapping.
- QoS: delay/jitter/loss bounds (G.114: 150 ms), IntServ vs DiffServ, EF/AF/BE.
- SIP call flow (INVITE-180-200-ACK), RTP/SDP, codecs G.711/G.729, STUN/TURN/ICE.
- Access: GPON, LTE; IPv6 necessity; FMC/VoWiFi concepts.
- Security: IMS-AKA, IPsec/TLS/SRTP, SBC functions, lawful interception.
- SDN/NFV definitions; 5G SBA, network slicing, CUPS.

SECTION SUMMARY

Anchor every answer in the layered architecture: identify the stratum, the protocol and the QoS/security mechanism - that pattern answers most CS642 questions.