Service Design Evolution in Future Internet

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Today’s Scientific Work in Telecommunications

Internet constraints

future application

science or repair shop?
Service Design Evolution in the Future Internet

1. Trends of Future Services
   - Intelligence Placement at Edge and User Initiated Service
   - Multi-Network Service and Multi-Platform Service

2. Edge-Based Service Design & Deployment
   - Overlay self-organizing control structure & dynamics
   - User Behavior: selfish and altruistic users
   - Functional Scalability & Stochastic Scalability
   - QoS Issues and Example: VoIP-Signaling Platform on Chord Ring

3. Challenges
   - From QoS to Quality-of-Experience
   - Trendscouting, Network Dimensioning, Adjustment and Management
   - Performance and Monitoring Issues
Trends observed and Questions

- Boundary between providers and users is disappearing
- Network dimensioning or reaction scheme design
- Stochastic scalability and network resilience
- Quality of service (QoS) or quality of experience (QoE)
Trends in Services and Platforms

- Who designs services?
  - Service design by network provider
    - classic way to design service, provider and platform-dependent
  - Edge-based service design
    - designed and deployed by user groups
    - transition from disruptive technology to business cases
    - edge-based intelligence & application-driven overlay structure
    - example: P2P content delivery
Overlay Control Structure

overlay structure supporting new service

NGN core transport network
Stepwise Traffic Change

- **P2P applications**: 67.4%
- **web**: 7.9%
- **OTHER**: 23.3%
- **FTP**: 0.3%
- **email**: 1.2%

Source: Telefonica 2004
Jose Enriquez
COST 279, Rome: traffic observed in a transit router
Intelligence Placement & Service
Services, Platforms and Networks

User A

User B

Services:
- Phone call
- Content Distribution

Platforms
- eDonkey
- BitTorrent
- KaZaA

Networks
- Wired Sensors
- UMTS

Platforms
- SIP
- POTS

Networks
- Wired
- UMTS
- Sensors
Trends in Services and Platforms

Who designs services?
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Transition to Multi-Network Services & Multi-Platform Services
- highly dynamic network topology and traffic growth
- customer behaviour changed, selfish users and applications
- QoS issues unclear: customer perceived or network provider defined QoS
Multi-Network Service

Service:
- Phone call

User A

User B

Platform

Wired

UMTS

Networks

Skype
Multi-Platform Service

Service:
- Phone call

User A

Platform

Skype

SIP

Networks

Wired

UMTS

User B
Multi-Platform: Interconnection of USN and Internet

RFID-based
Tag
Reader
RFID Network

CDMA2000 1X/ EV-do

MN+Sensor

Terminal-based Service

Public Internet

Access Node

Direct-based Service

AN

Gateway-based Service

USN NameServer

USN HA/ FA

USN Nodes
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Overlay Control Structure

- stochastic scalability
- stability (churn)?

- overlay structure
- supporting
- new service

- core
- transport
- network
- e.g. IP
Self-Organizing of Service Support

Node failure/leave
⇒ self-repair structure

Node joins
⇒ self-adapt structure
Example: Multi-Network (Vertical) Handover
Example: Multi-Network (Vertical) Handover

Overlay connection, e.g., Pastry

Peer
Thinning the protocol architecture

- Overlay adapted to underlying layers
- Increase efficiency and robustness

- Supporting transport over any kind of networks

- Heterogeneity of network technologies
- Interoperability between technologies
Thinning the protocol architecture

Application
Overlay
Presentation
Session
Transport
Network
Data Link
Physical

Application
Mediation
Connectivity
Thinning the protocol architecture

- user-centric, context aware, QoS, Quality of Experience
- allows multi-network-services with edge intelligence
- application-layer routing / content-based routing

- self-organized routing and distributed resource access
- autonomic network management
- allows dependable direct communication

- optimized for individual access network
- allows mobility of users and handover between technologies
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Selfish application: positive feedback bitrate

- Low QoS: increase packet/bit rate
- Still low QoS: introduce other counter measures (e.g., Codec change, app. layer re-route)

QoS assessment period

QoS assessment

30ms
Selfish application: some measurements

- Use NistNet to emulate network dynamics
- Test case: Skype VoIP application

- shapes traffic only for connection between user A and user B
- gateway for signaling traffic to the Internet

Audio file (51s) is repeated with a pause of 5s in between
End-to-end QoS measured in terms of PESQ value (computed for intervals of 56s)
Network characteristics (e.g. packet loss) evaluated using moving average (of 5min)
Emulating Dynamic Changes

packet loss
Bandwidth Adaptation Based on QoS

- Packet sent times depend on codec, independent on packet loss
- Variable bit rate by increasing packet size, i.e. more audio data
Bandwidth Adaptation Based on QoS

- Packet sent times depend on codec, independent on packet loss
- Variable bit rate by increasing packet size, i.e. more audio data

Application adapts onto experienced end-to-end quality (here: network measurements) to increase QoS: selfish behaviour
Bandwidth Adaptation Based on QoS

- Packet sent times depend on codec, independent on packet loss
- Variable bit rate by increasing packet size, i.e., more audio data

Packet loss is still increasing and might be caused by congestion, i.e., increased bandwidth worsens congestion.
Bandwidth Adaptation Based on QoS

- Packet sent times depend on codec, independent on packet loss
- Variable bit rate by increasing packet size, i.e. more audio data

Still low QoS: introduce other counter measures, here another voice codec is used (with smaller packets)
Bandwidth Adaptation Based on QoS

- Packet sent times depend on codec, independent on packet loss
- Variable bit rate by increasing packet size, i.e. more audio data

Application measures end-to-end QoS and reacts on it, i.e. edge-based intelligence
Bandwidth Adaptation Based on QoS

- Packet sent times depend on codec, independent on packet loss
- Variable bit rate by increasing packet size, i.e. more audio data

Application shows same behavior when restarting the experiment, i.e. intelligence managed by measurements and thresholds/states
Application-Driven Routing Based on QoS

- RTT > 500 ms results in strong PESQ degradation
- If RTT > 4 s Skype relays connection over third party machine

Influence of RTT on QoS is small, if RTT is small enough, i.e. below a threshold.
Application-Driven Routing Based on QoS

- RTT>500ms results in strong PESQ degradation
- If RTT>4s Skype relays connection over third party machine

Influence of RTT on QoS is strong, if RTT is large, i.e. exceeds a threshold.
Application-Driven Routing Based on QoS

- RTT > 500 ms results in strong PESQ degradation
- If RTT > 4s, Skype relays connection over third party machine

![Graph showing the relationship between RTT and PESQ](attachment:graph.png)

Application-driven routing based on experienced end-to-end quality: voice connection goes via Internet instead of (emulated) disturbed direct connection.
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Functional Scalability

2^2 nodes

2^5 nodes
Functional Scalability & Stochastic Scalability

Functional Scalability

\[ 2^2 \text{ nodes} \]

\[ 2^5 \text{ nodes} \]

Stochastic Scalability

\[ 2^4 \text{ nodes, stable stationary structure} \]

\[ 2^4 \text{ nodes, higher churn rate (joins and leaves)} \]
Stochastic Scalability

- **Functional Scalability**
  - If a solution works for 10 customers, does it also work for 100, 1000, \ldots, customers?
  - scalable for slowly changing network size and structure

- **Stochastic Scalability**
  - If a solution works for $X=100$ customers, does it also work if the network size $X$ is a stochastically varying random variable?
  - overlay network with high “churn rate”, fast changing network size and structure
  - networks resilience & survivability in case of stochastic breakdowns

- **Self-describing Networks?**
Example: P2P Voice-over-IP Signaling using Chord

Information Provider

IP Call

Information Seeker

Chord Ring as Signaling Network

Information:
- nick-name
- current IP-address
- user profile
Performance analysis of a VoIP Signaling Platform

- Voice-over-IP application with distributed P2P-based directories
  - **Architecture**: Signaling platform using Chord ring with distributed hash table
  - **Scalability**: how many customer can be supported by stochastically varying ring size due to “churns”
  - **Service Level**: 99% of directory searches need less than 1 sec

- Performance analysis with stochastic modeling approach
- Research cooperation with Siemens
Model parameters

\[ T_N \] one hop delay

\[ X \] number of hops until searched peer is found

\[ T_A \] delay of the answer

\[ T \] total search duration
Phase Diagram of a Search Process

Probability, that the searched peer is \( i \) hops away

\[ p_0 \]
\[ p_1 \]
\[ p_2 \]
\[ p_i \]
\[ p_k \]

\[ \text{search} \]
\[ \text{begin} \]

\[ \text{search} \]
\[ \text{end} \]
$T_N = T_A$

$T_N$: negative-binomially distributed

$c_{T_N} = 1$

$E[T_N] = 50$ ms
$E[T_N] = 50 \text{ ms}$
10000 customers

1 second

Signaling platform scales!
Quality of Service: Delay Quantile

- 0.9999-quantile
- 0.99-quantile
- 0.95-quantile

$E[T_N] = 50 \text{ ms}$

$c_{T_N} = 1$

- 0.75 sec

2000 customers
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End of Talk

Thank you!