1 Introduction

1.1 Current Environment

- Cause:
  - Advances in mobbile devices, easy to use, affordable and powerful
  - People can connect to Internet anytime, anywhere
  - Popularity of video-sharing websites
- Effect:
  - Mobile users demands increasing
  - Exponential growth in video traffic
  - Explosion in data traffic
- Problems:
  - Application requirements
  - Multiple Device Types
  - Different technologies
  - Different User preferences (cost, energy, quality)
- Solution
  - Coexistence of multiple technologies
  - Deployment of different radio access technologies in overlapping areas
  - Accomodate more and more subscribers
- Challenges:
  - Offer always best connectivity to the interet for mobile users
  - Ne on best availabel radio access network
  - Network optimization especially for video traffic
  - Provide continuous and smooth video streaming, minimal delay, jitter, and packet loss
  - Avoid degredation in video quality and user experience

1.2 What is QoS?

- What is quality?
  - "The totality of characteristics of an entity that bear on its abuility to satisfy states and implied needs"ISO 8402
  - "Degree to which a set of inherent characteristics fulfils requirements"ISO 9000
- What is QoS?
  - A subset of overall quality
  - "The collective effect of service performance which determine the degree of satisfaction of a user of the service"ITU-T Rec. E.800

2 Service Level Agreement

- Contract between ISP and Client
- ISP gives guarantees for delivery of service
- Service Level Objectives (SLO)
  - Goals needed to be met for service
  - Used to specify QoS desired
- Service Level Guarantees (SLG)
  - Promise to meet SLOs
- Service Level Managements (SLM)
  - Approach of ISP for operation and delivery of services
  - Integrated management of functionalities in SLA life cycle

2.1 Service Level Objectives

- QoS Parameters
  - Instance to represent QoS to customers
  - Different according to type of service
- Generic QoS params required in network service:
  - Availability, Delivery, Latency, Bandwidth, MTBF (Mean Time Between Failures), MTTR (Mean Time to Recover)

2.1.1 QoS Parameters

- Availability
  - % of feasibility of service in every service request
  - key parameter for customers
- Delivery
  - Converse of packet loss
  - % of each service delivered without packet loss
- Latency
  - δt packet to travel from service access point (SAP) to target and back
  - includes transport t and queuing delay
- Bandwidth
  - Used/Available capacity - Stated in SLA
- MTBF - Mean Time Between Failure
- MTTR - Mean Time To Recover
  - Avg. t device/sys takes to recover from failure

2.2 Service Level Guarantees

2.2.1 Customer requirements of QoS

- Focus on user-percieved effects
- Not depend on assumptions of internal net design
- Take into account all aspects of service from cusomers PoV
- Assured to user by ISP
- Described in net-independent terms, creates common lang. understandable by both user and ISP
  - ITU-TG.1010

2.2.2 QoS Offered by the Service Provider

- QoS metrics for web browsing
- Requirements:
  - Mainly influenced by response time (!> 5s)
  - Delay $< 400ms$ expected for best effort net traffic
  - Jitter not applicable to HTTP
    - Little impact on txt/picture web browsing
  - Data rate required b.w. $< 30.5kbps$
  - Expected loss rate error rate 0 since HTTP is reliable
    - Error reTX
- QoS Metrics for Video
  - Under diff. codec tech and quality req. diff. req. for net TX
  - VCR quality MPEG-1 stream:
    - B.W $1.2 - 1.5Mbps$
    - Jitter recommended $< 100ms$ for broadcast quality
    - Residual bit error rate $< 10^5$ for broadcast quality stream using compressed format
    - Loss/Error rates $< 10^5$
  - HDTV quality MPEG-2 video streams:
    - B.W $40Mbps$
    - Jitter $< 50ms$ for HDTV quality
    - Residual bit error rate $< 10^6$ for HDTV quality stream using compressed format
    - Loss/Error rate $< 10^6$
  - MPEG-4 video streams:
    - B.W $28.8 - 500kbps$
    - Jitter $< 150ms$ due to lower quality req.

        * MPEG-4 has higher comp. rate, $\therefore$ less residual error
        * Loss/Error rate $< 10^5$

- Statement of level of quality actually achieved and delivered to customer
- should be same as offered QoS
    - Determine what was actually achieved to asses level of performance achieved
- Performance figures summarised for specified periods of time

QoS Percieved by Customer

- Statement expressing level of quality exp.
- Perceived QoS - Degrees of Satisfaction, not in tech. terms
- Mean Opinion Score (MOS) specified by ITU-T Rec. P.800

2.3 Service Level Management Functions

- SLM categorized into seven functions:
    - SLA creation
        * Create SLA template for specified services
    - SLA Negotiation
        * Selecting applicable QoS params. in SLA
        * Negotiating penalty in case of SLA violation
    - SLA Provisioning
        * SP configure the network element/topology to provide service
    - SLA Monitorimg
        * SP must verify degree of SLA assurance
        * Perform surveillance on QoS parameter degredation/violation
    - SLA Maintenance
        * In case of QoS violation, analyses readon why degredation has occured, which params. degraded
        * Notifies SLA provisioning to restore service
    - SLA Reporting
        * Provides performance info to customers, periodically or on-demand
    - SLA Assessment
        * Demands payments to customers
        * Accommodates customers with penalty when violation occurs
- SLA provisioning and monitoring most important in net management layer

2.3.1 SLA Monitoruing

- Input
  - QoS Parameters
  - SLA Contract
- SLA Monitoring
- Output
  - Problem Notification
  - Performance

3 Network Performance Metrics

- Network Performance Metric (NPM)
  - Basic metric of performance metric in net management layer
- Four Types:
  - Availability:
    - % spec. t interval in which sys was available for normal use
    - What is supposed to be available?
      - Service, Host, Network
    - Reported as single monthly figure
      - 99.99% means service is unavailable for 4 minutes during a month
    - Test by sending syutable packets, observing answering packets (latency, packet loss)
    - Metrics:
      - Connectivity: Physical connectivity of network elements
      - Functionality: Whether associated sys works well or not
  - Loss:
    - Fraction of packets list in transit from host to another during specified t.
    - Packet transport works on best-effort basis
    - Moderate level of packet loss not in itself tolerable
      - Some real-time services can tolerate some losses e.g. VoIP
      - TCP resends lost packets at slower rate
    - Metrics:
      - One way loss
      - Round Trip (RT) Loss
  - Delay:
    - t taken for pkt to tracel from host to another
    - $RTDelay = ForwardTransportdelay + Serverdelay + backwardtransportdelay$

        * Forward transport delay often $\neq backwardtransportdfelayPingstillmostcommonlyusedtome$
* Delay changes as conditions on net. vary
        · e.g. Server load, traffic load, router load, routing function
* For streaming, high delay/jitter (delay variation) can cause degredation on user-perceived QoS
* Metrics
        · One Way delay
        · RT Delay
        · Jitter

- Utilization:
    * Throughput for link expressed as % of access rate
    * Throughput:
        · Rate data is sent through net. (b/s, pkt/s, flows/s)
    * Metrics:
        · Capacity
        · B.W
        · Throughput