**Problem 1**

1. **Network Planning**
   * Since more traffic will be introduced into the network, they will make sure that the network will always maintain an adequate capacity so that there are no interruptions
   * Additionally, they will work with the network forecast group to provide a short term and long-term 5G capacity plan.
   * They will design the 5G network architecture and any upgrades, and hand them over to the network operations unit for deployment.
   * Provide a yearly plan on network upgrade/modernization
   * Identify links and routers/devices that are approaching capacity threshold; and issue capacity augment ticket to initiate new capacity build.
   * Design and develop business cases for network footprint expansion, by working with the technology development team and economics team.
2. **Technology Development**
   * Equip ABC Inc. with state-of-the-art technology and solutions to make sure the 5G network can support the next generation of services and applications. Also, to stay competitive in the market.
   * Work with the network planning team so they can include the new technology driven upgrades in their network design and plan.
   * Develop technical guidelines to bring down the traffic unit cost for the 5G network.
   * Vendor negotiations to get the best deal on 5G equipment.
3. **Network Operations**
   * Responsible for keeping 5G network running 24/7 once it is up.
   * Receives 5G network design and plan from planning unit. Implements it.
   * Maintain 5G network once it is running. (QoS 24/7, monitor for failure and initiate steps to fix it)
   * Issue and manage 5G network maintenance and repair tickets.
   * Collect and analyze network health related stats. Analyze the data for issues.
   * Design and manage all network change management activities.
4. **Network Economics**
   * Develop cost models to provide costing details for 5G network. Also, provide costing for architecture/infrastructure.
   * Update the existing cost models based on new network changes and upgrades
   * Work with network planning team to provide economic/financial input to evaluate network business cases.
   * Respond to regulatory (CRTC) enquiry and questions.
5. **Network Forecast**
   * Network Capacity Planning ̶ Aid network planners to plan and acquire necessary network resources to meet future traffic growth.
   * Capital Forecast ̶ Assist the finance department to optimally allocate financial resources in order to meet future traffic growth.
   * Revenue Forecast ̶ Assist strategic/finance department to estimate 5G’s future years revenue coming from various services.
   * Service Growth ̶ Assist strategic planning/product/marketing BUs to analyse the current and future market trend.

**Problem 2**

Main Factors Contributing to Latency:

1. Transmission mediums (guided and unguided)
   * Capacity and speed vary depending on the medium. E.g. Fibre optic vs coaxial.
   * Guided mediums are generally faster than unguided.
   * Depending where the sender and receiver are changes which medium is used.
2. Propagation delay
   * The amount of time it takes for a packet to travel from one source to another. Depends on the distance between hosts and the transmission medium.
3. Queueing delay
   * The time that a packet waits to be processed in the buffer of a switch. The delay is dependant on the arrival rate of the incoming packets, the transmission capacity of the outgoing link, and the nature of the network’s traffic.
4. Transmission delay
   * The time it takes to transmit a data packet onto the outgoing link
   * Delay is determined by the size of the packet and the capacity of the outgoing link.
   * Larger size packets may take longer.
5. Processing delay
   * The time taken by a switch to process the packet header
   * Each hop a packet takes from router to router increases latency time.
   * Depends on the processing speed of the switch.
6. Packet Loss
   * Can be caused by network congestion, problems in hardware, software errors and security threats.
   * Depending on the application, packet may need to resent, thereby increasing latency.
7. Heavy network traffic
   * Higher number of customers are using the internet and cause network congestion.
   * Routers become congested and overloaded. Transmission links are at capacity.
8. Breakdowns
   * Routers and transmission links break down causing packets to reroute or get lost.

**Network Planner Changes**

1. Upgrade transmission links and routers
   * Upgrade to the latest routers so that they can process handle more traffic.
   * Better router processor improves the processing time.
   * Better and faster memory increases queueing buffer and thereby decreases packet loss and queuing delay.
   * Upgrading to latest transmission link (Fibre) increase the transmission rate and reliability.
   * Try to change FTTN to FTTH.
2. Use Proactive QoS metrics and stats
   * Metrics and stats will pinpoint problems in the network and allow for improved latency.
   * Customers with issues will be identified and better served.
3. Collaborate with the network forecast department to understand future traffic growth
   * Decreases the likelihood of future latency problems related to traffic
   * Can plan with other departments to change and upgrade network to prevent latency.
4. Review and make changes to the ISP architecture
   * Add more routers and links if more traffic is estimated.
   * Provide more forms of redundancy by using only a certain percentage of router slot capacity and link capacity. Also provide more routing paths for packets.

**Problem 3**

Web-browsing application

1. Load Time
   * How long the web browsing application takes to load
2. Page quality
   * Clarity of the images and text on the screen (Not distorted).
3. Crash Rate
   * Number of times the application crashes (becomes unusable).
4. Responsiveness
   * Amount of time it takes to interact with the application (e.g. clicking a button takes you to the top of the page. If it takes a while for the task to occur, it is not very responsive)
5. Lag
   * Speed of application as more data becomes available.

Video conferencing call application

1. Video quality variation
   * Changes in video quality (i.e. Resolution changes from 1080p to 480p)
2. Audio-video sync
   * Audio matches the correct time stamp of the video (i.e. audio matches the lips of the speaker)
3. Echoing
   * Audio is repeating itself very quickly.
4. Time to connect
   * The time it takes to join a meeting and be able to hear audio and see video.
5. Freeze
   * Long stoppage in either audio or video.