CABLELABS LITERARY SURVEY
6.7.11

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CAPABILITY OF IEEE 802.11G NETWORKS IN SUPPORTING MULTIPLAYER ONLINE GAMES

Abstract—focus on the highly interactive first-person-shooter games.

Examined: Factors such as the number of game clients and the amount of background traffic

- interested to learn that in a typical shared 802.11g network, how many game clients and how much background traffic can be accommodated

Results: the amount of background traffic has a significant impact on the latency and the loss ratio of the game traffic between the game clients and the game server, which in turn affect the observed game performance greatly.

Factors affecting performance: amount of non-game traffic, the wireless protocol, and the physical environment parameters (such as the distance and the clearance of sight between wireless clients and access points, the humidity, and the interference with other wireless devices)

Background info: The IEEE 802.11 standard suite includes multiple modulation techniques, all of which use the CSMA/CA media access control (MAC) protocol.

- maximum raw data rates of 11 Mbps and 54 Mbps
- in almost all cases the observed throughput of UDP traffic is well below 50% 54 Mbps.

Test bed: 10 machines. These include:

  (i) A game server (GS) (ii) Seven game clients (GCs) (iii) A background traffic server (BS) (iv) A background traffic client (BC)

- The GS and the BS are on a wired network, and are connected together with the wireless access point via an U.S. Robotics 8054 Router.
- The test bed was set up in a relatively isolated environment where there is no physical obstacles between the wireless access point and all the client machines.
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Test Bed Continued:

- The access point was configured using most of the default settings. This way, only the wireless clients on the test bed could access their Wi-Fi network.
- There were two other Wi-Fi networks that were in operation in the same building, which were observed to have a “low” signal strength. To reduce the interference from those two networks, the access point was configured to make use of the least busy channel.
- Environment was deemed adequate because in a targeted wireless gaming environment, coexistence of multiple Wi-Fi networks may be likely and some (low) degree of interference may be present.

**Two types of traffic**: Game Traffic and Background Traffic

The **game traffic** is sent between individual GCs and the GS.
- A traffic emulator for the game Half-life was used to generate the game traffic.
- On average one packet is sent every 60 ms; the packet size follows a LOGN dist. (203, 0.31) bytes.
- When there are more than one GCs in the game session, at each timeout, the GS sends one packet to each GC in a row.
- From each GC to the GS, on average one packet is sent every 41.5 ms, its size follows a NORM dist. With parameters (71.57, 6.84) in bytes.
- At the beginning of an experiment, the GS waits for all GCs to initiate a connection. After they do so, the GS sends packets to the GCs back-to-back in a row at each timeout, following the order in which the connections were first initiated.
Background traffic is generated and sent from the BS (wired) to the BC (wireless).

- This direction was chosen because initial experiments indicated that the network-level performance is much more significantly affected by the background traffic sent from the BS to the BC, when compared to that in the opposite direction.
- The generated background traffic shares the Wi-Fi network bandwidth with the game traffic.
- A C program was written to generate and send messages with a fixed size at regular time intervals using UDP. Various levels of offered load were experimented.
- In order to decide on the length of the regular time interval, the accuracy of the operating system timer was evaluated using Ethereal
  - Results: 10 ms interval, the background traffic bandwidth achieved is only 90% of what is specified.
  - 50 ms interval, the accuracy reaches 99%
- The message size is calculated based on the level of offered load of the background traffic. For example, to achieve an offered background traffic load of 16 Mbps, a message size of 100 Kbytes was used.
- If the size of a message is larger than the maximum UDP payload length, the message is fragmented into multiple UDP segments which are then sent back-to-back to the BC. Background traffic is started at the beginning of each experiment.

Performance metrics of the experiments are:

(i) the packet loss ratio, LRs2c, for game packets from the GS to the GCs
(ii) the packet loss ratio, LRc2s, for game packets from all the GCs to the GS, and
(iii) the average round-trip-time, RTT, from a GC to the GS.

Experimental Design

1. Experimented with two factors:
   - studied their impact on the game performance
   - number of GCs (NC)
   - amount of background traffic (BT),
   - NC denotes the total number of GCs that are simultaneously accessing the GS via the experimental Wi-Fi network. BT denotes the bandwidth usage of the background traffic.
2. We first used a $2^2$ factorial experimental design to determine the relative importance of each factor.
   - Lower and Upper bound levels for NC: 1 and 7 mainly based on available resource.
   - LB and UB levels for BT: 16 and 32 Mbps.
3. Each experiment is performed for a duration of 8 minutes. (This length was considered representative of a typical FPS game session)
4. Each experiment is repeated multiple times.

Effect of the Number of Game Clients

RTT performance of the game traffic against the number of game clients
(1) the RTT when BT = 16 Mbps is much lower than that when BT = 32 Mbps. This is as expected because the higher the load of the background traffic, the less capacity that is left to the game traffic.
(2) For both values of BT, RTT is well below the target 60 ms level.
(3) RTT is not significantly affected by the number of game clients for the scenarios that we experimented.
Thus conclude that in terms of game traffic RTT, when the number of game clients in an 802.11g network is seven or below, a large amount of background traffic can be offered to the network without jeopardizing the game performance.

Loss ratios as a function of the number of game clients
(1) the loss ratio slightly increases as the number of game clients increases beyond 3.
   Thus conclude that in terms of the loss ratio for traffic along the GS→GC direction, which is also the direction of the background traffic, the number of game clients has noticeable but slight impact on the performance.
(2) We also noticed that when there are more than one GCs, looking at the individual GCs loss ratio results, the loss ratio increases following the order in which the GS sends packets to the GCs.

Effect of the Amount of Background Traffic
(1) as the amount of background traffic increases, for both cases, RTT increases
(2) Regardless of the amount of background traffic, the values of RTT are all well below the target 60 ms level.
   Thus conclude that in terms of average RTT, the experimental 802.11g network is adequate for supporting the FPS game of our choice, even though the network may be heavily loaded with background traffic.
   Also the amount of background traffic greatly affects the loss performance when the background traffic is sharing the wireless network capacity with the game traffic.

Final Conclusion & Recommendations:

When there are up to seven game clients in the wireless network, the amount of back-ground traffic has the major impact on performance. In order to ensure a good game playing experience, the amount of background traffic should be kept below 16 Mbps.
ANALYZING THE NETWORK TRAFFIC REQUIREMENTS OF MULTIPLAYER ONLINE GAMES

Abstract - propose the measurement of the network traffic requirements of the most popular MMOGs by monitoring the network traffic generated by different game tournaments in a LAN Party.

Methods: Peer-to-Peer architectures have were proposed for MMOGs

Results: show that the aggregated band width required by these applications is not higher than 1600 Kbps.

Two kinds of games: (1) inbound traffic bandwidth lower than the outbound traffic bandwidth (2) inbound traffic bandwidth whose average values are very similar to the output traffic bandwidth values.

Evaluation: the game servers were put in a subnet different from the one used by the users.

The different subnets were linked by a switch.

The switch was monitored, obtaining all the traffic (IP headers) generated by the game tournaments.

Ran Study for 24 hours, Filtered the trace file, selected traces belonging to different game protocols, identified the servers and the clients involved in each game. Finally, computed the bandwidth required in each game

<table>
<thead>
<tr>
<th>Aggr. Bandwidth</th>
<th>1600 Kbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inbound B.</td>
<td>200-450 Kbps</td>
</tr>
<tr>
<td>Outbound B.</td>
<td>400-1100 Kbps</td>
</tr>
<tr>
<td>Inbound/ client</td>
<td>30 Kbps</td>
</tr>
<tr>
<td>Outbound/ client</td>
<td>74 Kbps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aggr. Bandwidth</th>
<th>1000 Kbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inbound B.</td>
<td>550 Kbps</td>
</tr>
<tr>
<td>Outbound B.</td>
<td>550 Kbps</td>
</tr>
<tr>
<td>Inbound/ client</td>
<td>25 Kbps</td>
</tr>
<tr>
<td>Outbound/ client</td>
<td>25 Kbps</td>
</tr>
</tbody>
</table>
Bandwidth requirements for a single client can be related to requirements by the rest of the clients.

**Final Conclusion** - The results show that the aggregated bandwidth required by these applications is not higher than 1600 Kbps.

Two kinds of games: (inbound < outbound traffic bandwidth, inbound ≈ the output traffic bandwidth values. Finally, the results show identical variations in the network traffic sent by the game server to the clients.

<table>
<thead>
<tr>
<th>Game</th>
<th>Client Computer</th>
<th>Server</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counter Strike</td>
<td>Outbound 47 kbps</td>
<td>Inbound 85 kbps</td>
</tr>
<tr>
<td>Quake III</td>
<td>60 kbps</td>
<td>200 kbps</td>
</tr>
</tbody>
</table>

Table 3 Final Bandwidth Recommendations
**Empirical Study of Subjective Quality for Massive Multiplayer Games**

**Methods**
- Standard pc running WoW w/o modifications
  - ADSL line, downlink rate of 2Mbit/s and uplink rate of 512kbit/s
- Pc connected to internet through *dummynet*
  - Introduces intermediate layer into the protocol layer to be adjusted by user that adds additional network delay to internet access (allows user satisfaction to be evaluated for different levels of jitter and delay)
    - Increased in steps of 20ms up to 200ms for each step ran all of the different jitter settings
    - Jitter was modified in steps of 10ms
    - There were 15 different settings for each user
    - Testing lasted between 3 to 5 minutes
- ITU recommendations (subjective testing of interactive multimedia applications)
- ACR (absolute category rating) category judgment method
  - One test sequence at a time and rated independently on a category scale
  - Users rated the quality they perceived in their opinion on a scale from five to one

**Measurements**
- User satisfaction concerning input parameter delay
- TCP delay based on packet dumps from *wireshark*
- RTT (round trip times) estimated by Karn’s algorithm (lost packets retransmitted)
- Principal Component Analysis (delay and jitter) and Pearson (linear) correlation factor
  - MOS = 5.17 - .012*Delay - .018 * Jitter \(\Rightarrow\) performance of proposed metric 97.14%

**Results**
- Delay has a stronger influence on MeanOpinionScore than jitter
- Increased delay has a negative impact on subjective quality
- Increase of delay variation has a negative impact on subjective quality
- The MOS score of WoW depends mainly on delay, but it is less sensitive than FPS games
A MEASUREMENT STUDY REGARDING QUALITY OF SERVICE AND ITS IMPACT ON MULTIPLAYER ONLINE GAMES

Methods:

- Bot driven test bed that explores the effectiveness of an automated latency balancing application
  - Allows for limited number of users and experiments
  - Keeps user behavior stable and allows focusing on network conditions for extended periods (minimizes unfair advantage given by player skill and uncontrollable network conditions)
  - Connect to switch via network bridge (wired) or access point (wireless) that introduces delay, jitter, and loss to individual packets
  - Separate wired controls to automate experiments using SSH Launcher scripts
  - Used SlugBot to simulate human players (can configure parameters accordingly)

Measurements and Results:

- Players connected via ethernet have no measurable advantage over IEEE 802.11 wireless players
- Delay influences the score and win probabilities significantly whereas the direction in which delay occurs does not.
- Jitter only has a marginal impact on score probabilities.
- The impact of loss depends on the direction, i.e. impact depends on whether loss occurs in client to server direction, vice versa, or in both directions
- Probabilistic models to predict the statistics of the outcome of games
  - In score limited games
    \[ P[\text{win}] \approx P\left[ \mathcal{N}(0,1) < \frac{\sqrt{m}}{\sqrt{1-p}} \right] \]
    where \( \mathcal{N}(0,1) \) is a standard normal random variable
  - In time limited games
    \[ P[\text{win}] \approx P\left[ \mathcal{N}(0,1) < \frac{\sqrt{\frac{\lambda_1 - \lambda_2}{\sigma_1^2 \lambda_1 + \sigma_2^2 \lambda_2}}} \right] \]
**IRS: A Detour Routing System to Improve Quality of Online Games**

- **Methodology:** Performed study by collecting extensive traces for RTT, analyzed traces to quantify potential performance gain of detour routing, and implemented a complete IRS system for online games.

- **Measurements:** They proposed an Indirect Relay System (IRS) to forward game-state updates over detour paths in order to reduce the round-trip time (RTT) among players.

- **Results:** IRS system improves the online gaming quality from several aspects, while incurring negligible network and processing overheads. With proposed IRS system, more than 80% of game sessions achieve 100 msec or higher RTT reduction.
Experimental Study of an Online Game over Wireless Networks

- Methodology: Implemented a two-player competitive online game over wireless LAN and tested its performance.
- Measurements: Goal was to reduce the impact of message delay.
- Results: Experimental results show that even with a high bit error rate, the application-layer quality deterioration is negligible for most game players.
STUDY THE TRAFFIC DIFFERENCE OF ONLINE GAMES BETWEEN GPRS/EGPRS AND ADSL NETWORKS

- **Methodology:** Analyzed the performance analysis and traffic modeling of the massive multiplayer online role playing games (MMORPG) in the presence of different access networks which include GPRS/EGPRS and ADSL.

- **Measurements:** They selected a popular MMORPG, collected sufficient data from emulated GPRS/EGPRS networks and real ADSL network, and based on statistic analyzing built the particular source models for game server and client independently.

- **Results:** Results show that being affected by network bandwidth and delay parameters, the statistic characteristics of the online game traffic behave differently in these heterogeneous access networks, leading to different game performance and player experience.
**Improving Online Game Performance over IEEE 802.11n Networks**

- **Methodology**: Conducted research by analyzing the results of conducted simulations under heavy background traffic.
- **Measurements**: They investigated the efficiency of IEEE 802.11n MAC layer mechanisms in improving quality of service of real-time FPS online games.
- **Results**: Analysis show that Transmission Opportunity (TXOP) mechanism is the key to improve the networking fairness of real-time online games and with reverse direction mechanism, MOS can be further enhanced.
A CROSS-LAYER DESIGN TO IMPROVE QUALITY OF SERVICE IN ONLINE MULTIPLAYER WIRELESS GAMING NETWORKS

- Methodology: Concentrated on a centralized server gaming architecture where wireless users can also connect to the gaming service; introduced a new scheme for estimating the packet loss rates and used information in a cross-layer design for improved overall quality.

- Measurements: Proposed an adaptive forward error correction (FEC) and rate control technique to improve service quality in a wireless gaming environment.

- Results: The proposed rate control scheme is TCP-friendly and thus should be well accepted in the research community. It is believed that the QoS guarantee model should provide high throughput and make wireless gaming a success in the near future.
ARCHITECTURAL CONSIDERATIONS IN ONLINE GAME SERVICES OVER DSL NETWORKS

- Methodology: Reviewed architectural considerations in the design of networked games, with a focus on communications aspects.
- Measurements: Considered architectural aspects on online games in the context of digital subscriber line (DSL) networks.
- Results: Provided a brief review of recent enhancements to DSL architectures and then proposed an architecture to provide online game services using an ASP model over a DSL access network infrastructure.
A Generalized Prediction Model of First Person Shooter Game Traffic

- **Abstract** - Present techniques for creating representative models for N-player FPS games based on empirically measured traffic of 2-player games. The models capture the packet size distribution as well as the time series behavior of game traffic.

- **Examined** - long range and/or short range correlations in the traffic, using 7 FPS games and different numbers of players (3+ players since previous studies focused on 2 players)

- **Results**: using their specific model (FARIMA), they showed how the model of a two-player game can be extrapolated to games with larger numbers of players by deriving a generating PMF for the residuals of the FARIMA model. (Their model proposed a better way to measure traffic with any amount of players)

**Extrapolation** - Estimating a function at a point which is larger than (or smaller than) all the points at which the value of the function is known.

**Probability Mass Function (PMF)** is a function that gives the probability that a discrete random variable is exactly equal to some value.
SUMMARY

- Analyzed network bandwidths moving in both directions
  - Wireshark
  - Ethereal
- Background Traffic & Game Traffic
- RTT (Round Trip Times)
- LAN and WAN Parties were used
- Dummynets
- MMOGs, FPS