MMORPG Player Actions: Network Performance, Session Patterns and Latency Requirements Analysis

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Abstract – Providing Massively Multiplayer Online Role-Playing Games (MMORPGs) is a big challenge for future mobile, IP-based networks. Understanding how the players' actions affect the network parameters, the game platform, and the overall perceived quality is highly relevant for the purposes of game design, as well as for the networking infrastructure and network support for games. We break player actions down into discrete categories, and show that each category is distinct in terms of several key metrics. We discuss which categories of actions could be supported on current mobile devices, and present evidence in form of a user survey demonstrating the demand for such services. The starting points into the discussion include the networking, session and latency requirements for particular player actions on one side, and the players' interest on the other. The Blizzard Entertainment's World of Warcraft (WoW) is used as a case study.

Keywords: MMORPG, networked game, player activity, performance, patterns

Introduction

As the old saying goes, "You're never too old to play" – and even more so in a broadband, and ever increasingly mobile, online world. According to the report from DFC Intelligence, the worldwide online game market is predicted to grow from USD 4.5 billion in the year 2006 to over USD 13.1 billion in the year 2012 [1]. The genre of Massively Multiplayer Online Role-Playing Games (MMORPGs), offering immersive and wonderfully diverse, persistent multi-player virtual worlds, constitutes a significant part of that market. With 11.5 million subscribers, the most popular MMORPG is Blizzard Entertainment's World of Warcraft (WoW) with 68% of the subscription market, while other successful MMORPGs include RuneScape, Lineage, and EVE online [2, 3].

The challenge and motivation to make such MMORPGs available on mobile devices is clear, but so are the limitations. Still, some "PC games" have already been ported to mobile devices, such as Quake for iPhone [4] and Age of Empires for Pocket PC [5], while Path of a Warrior MMORPG has been initially designed for mobile phones [6]. Cross platform MMORPGs offer even more revenue possibilities as they have a broad subscriber base, while introducing mobile access for already existing virtual worlds allows for an "always present" feature. Interestingly, network traffic measurements in the METAWIN project [7], taken within the core network of one of the mobile operators in Austria, have shown that WoW is in the top

ten TCP services and sums up to nearly 1% of the total TCP traffic – a relatively large value for a mobile network. It is evident that users do play MMORPGs over mobile connections, even though the game is not ported, nor adapted for mobile devices.

Players may perform various activities in MMORPGs, from exploring virtual worlds to interacting with the environment and other players in various ways. Typical interactions include combating other players or computer controlled monsters, earning and making virtual goods by trading or crafting, and socially interacting with other players. As the context of the virtual world can vary significantly, it becomes necessary to understand the implications of users' actions on the network parameters, the game platform, and the overall perceived quality. This knowledge is highly relevant for the purposes of game design, as well as for the networking infrastructure and network support for games.

The amount of time players spend performing certain types of actions can be a significant factor in game evolution towards mobile platforms, as well as in business models for games. Network providers (especially mobile) could use the information on networking characteristics of player actions in order to implement Quality of Service (QoS) support [8], or to model and design appropriate links for game servers or proxies. The categorization of player actions is the first step in that direction.

In this paper, we break player actions down into discrete categories, and show that each category is distinct in terms of several key metrics. We discuss which categories of actions could be supported on current mobile devices, and present evidence in form of a user survey demonstrating the demand for such services. The starting points into the discussion include the networking, session and latency requirements for particular player actions on one side, and the players' interest on the other. As a case study, we use WoW. The paper is organized as follows. After the related work section following next, in Section 2 we describe the five categories of player actions: questing, dungeons, trading, raiding, and player versus player (PvP) combat. The methodology for data collection and analysis is described in Section 3, and the measurements and results are described in Section 4. Section 5 concludes the paper.

1. Related work

We now briefly summarize the findings in the related research work in the areas of MMORPG network traffic characterization, session characteristics, user studies related to interest for MMORPG on mobile platforms, and latency.

Referring to MMORPG network traffic, a lot of work has been done on mathematical modeling and analysis of traffic characteristics, as well as on transport layer (mainly, Transmission Control Protocol (TCP)) protocol mechanisms. Svoboda, Karner, and Rupp [9] argue that the delayed acknowledgements algorithm in TCP is a bad choice for MMORPGs, because it contributes to delay in the communication between the client and the server. Kim, Choi, Chang, et al. [10] analyze the traces captured on the server side of the MMORPG *Lineage II* and show that the major characteristic of the MMORPG traffic is asymmetry of

upstream and downstream traffic. Fernandes, Antonello, Moreira, et al. [11] analyze Second Life (SL), and show that the traffic patterns of SL differ significantly from traditional MMORPGs, especially in that they have much larger bandwidth requirements. The authors have also noted that the traffic characteristics are highly dependent of the number of users in the vicinity and the action currently performed (i.e., walking, flying, or standing), but they do not investigate this issue further. Chen, Huang, and Lei [12] have performed very extensive research on traffic patterns of MMORPG game *ShenZhou Online*, which they later extend with the critique of TCP as the base protocol for MMORPGs [13]. To the best of our knowledge no work has been done on traffic characterization with respect to player actions in MMORPGs. We presented our initial work in this area in [14].

Relevant research related to MMORPG session duration may be summarized as follows. Chen, Huang, Wang, et al. performed measurements of session duration time as related to network QoS [15]. Analysis of WoW player's game hours was done by Tarng, Chen, and Huang [16], and by Zhuang, Bharambe, Pang, and Seshan [17], with analysis of active playtime, downtime, and virtual world geographical distribution of users. Svoboda, Karner, and Rupp [9] compared the session time on mobile connections to the session time on fixed connections, and although mobile sessions were shorter, it was not to a great extent. Compared to our work presented here, the main difference is that they studied overall session times, and did not measure nor study how much time users spend in doing specific actions in the virtual world. Context based services for virtual worlds were studied by Bergsträsser, Hildebrandt, Lehmann, et al. [18], who developed a framework for adding virtual context based services.

User interest in mobile version of MMORPG was examined by Koivisto and Wenninger [19], who found out that users are mostly interested in communication aspects and access to trading system in the game. According to Roy [20], adding mobile component to an MMORPG would increase mastery and user involvement in the game. By conducting a research study among real gamers, Johnsson [21] has shown that MMORPG players want communication through text chat the most, followed by voice communication, and game features like trading, skill management, and crafting coming last on the list of desired features within a mobile context.

Latency dependencies have been a subject of research for all interactive networked multimedia applications since their inception. Acceptable latency values for MMORPGs appear to be game-specific, but within the certain bounds. Fritsch, Ritter, and Schiller [22] have determined that test game *Everquest2* runs smoothly with latencies of up to 1250 ms. They monitored the time in which user kills a certain number of monsters, and the remaining health and magic points that users have after the encounter. Dick, Wellnitz, and Wolf [23] performed a player survey and analysis of how latency affects player performance in different games, and among them a single RPG *Diablo 2* which showed that players think of latencies around 80 ms as the optimal, and those around 120 ms as the maximum tolerable value.

Claypool and Claypool [24] categorized player actions by latency, using a precision/deadline plane.

2. Action types in MMORPG

In a typical MMORPG, the player controls a virtual character (called *avatar*) which represents the player in the virtual world. The MMORPG virtual worlds are usually vast and complex. For example, the virtual space of the original WoW without expansions is 113 square kilometers [25] and the Lord of the Rings Online (LOTRO) virtual space without expansions is 50 square kilometers [26]. In such virtual worlds, there are many things a player can do, depending on the story of the game, but most MMORPGs do share some common characteristics. Several fundamental elements may be identified in most MMORPGs: some form of progression, social interaction within the game, in-game culture, system architecture, and character customization. In this work we focus on player progression, as in most games this is the player's primary goal [27]. Progression can be achieved through upgrading the player's avatar by level or skill points, equipment, and other means, like in-game wealth or "achievements" (records of certain tasks performed). To progress in the game, the players typically fight monsters and perform quests. The *quests* include specific tasks given by Non-Player Characters (NPCs). Both actions can be done either alone or in a group, and usually provide a reward in form of experience points. We do not examine social interaction among players in detail but it is evident that it permeates every aspect of the game.

We now list and describe the player actions, using the following metrics (properties):

- Number of actively participating players (other players in the vicinity of the observed player in the virtual world, which (may) in some way affect the player);
- Required cooperation amongst participating players;
- Rate of player activity (dynamics of player's input);
- Mobility of the player in the virtual world;
- Number of actively participating NPCs;
- Combat requirement;
- Communication aspect (need for additional means of communication, most often text or voice).

As a case study of MMORPG application we use WoW, which has a fantasy based virtual world with elves, orcs, and other fantasy races. Like many other MMORPGs, WoW is based on client/server architecture, with multiple servers. The virtual world of WoW is replicated on many servers (server *shards*), with each server handling a complete copy of the WoW virtual world. Only the players using the same server can communicate and interact with each other. The description of MMORPG player actions following next is illustrated by examples from WoW.

Trading virtual goods is an important part of almost all MMORPGs. In WoW trading can be done between player and a NPC, between two players, or through Auction House (AH), in

which players may create auctions for virtual items and buy items from other players. In this action type, only one or at most two players are involved, the game play pace is very slow, and the amount of movement and interaction with other players is limited. There is a number of other players and NPCs around, but a trading player typically interacts only with the other party involved in the trade (another player or a NPC). There is no need for highly coordinated collaboration amongst players, as the task of trading is fairly simple – the players just need to "meet" in the virtual world and exchange the items for money by using drag-and-drop in the trade window. This type of activity does not include combat, nor does it require additional means of communication. Progression achieved by trading is manifested in form of acquiring in-game money ("gold") and virtual items.

Professions usually consist of some sort of crafting activities and gathering of virtual items. Combined with trading, professions make the base of all virtual economies [28]. The total number of available professions in WoW is twelve, but the player's character can only learn two "main professions" and three "secondary professions" at any one time. *Crafting professions* can be easily separated from others, as players usually engage in them in towns and cities with access to a bank or an AH, in order to obtain needed materials, store them, or sell their crafting products. *Gathering professions* are based on retrieving virtual items from various places in the world (e.g., mining ore for weapons, picking rare herbs for healing potions). Gathering professions are usually heavily interleaved with questing (e.g., a player gets a task to kill ten giants, but while searching for them he finds an ore deposit and mines it), and will thus not be considered further under this category; hence we base the characterization of professions on crafting. (More on interleaving of different action types, including gathering and questing, will be said later.) Characteristics of the crafting action type are a single player activity and a very low action rate. While crafting, the player must stand still in order to succeed in crafting an item, as moving cancels the action; hence, this action type may be characterized as having zero mobility. Even though there is usually a number of other players and NPCs around, the player does not interact with them while crafting. As this is a "solo", i.e. single player activity in WoW, it does not require interaction, coordination, and communication with other players. Players are still interconnected through professions as they need products which only other professions provide (e.g., in order to make a certain explosive, *engineers* need a liquid which only *alchemists* can make). Professions are peaceful activities which do not involve combat. Progression achieved trough professions is same as through trading (acquiring gold and virtual items).

Dungeons in WoW are instanced confined areas of the virtual world that only a limited number of players can enter [27]. As dungeons are strictly designed for a given number of players, they constitute the main small group activity in WoW. Mechanisms similar to dungeons exist in all MMORPGs, enabling a group of players to jointly reach a goal which would not be attainable for a single player. In WoW there are also other incentives to encourage grouping, such as more difficult quests, which, for example, require more players

and some forms of PvP combat, but dungeons are the primary grouping mechanism as they require a specific group setup, and also a relatively high time for completion, as shown later in this paper. Dungeons require an organized and highly coordinated group of players which often require additional communication. A group may, for example, involve a "tank", as a character who absorbs enemy blows and protects other members of the team; a "healer", as a character responsible for keeping up the health of the party; characters which inflict damage (often referred to as "DPS", meaning Damage Per Second); and those who temporarily control the mobs and make them lose control of actions and abilities (Crowd Control, or "CC", characters). A "mob" is a special kind of NPC, the primary purpose of which is to be killed for experience, quest objective, or "loot" (items taken from "dead" mobs). Each dungeon instance is created for a single player group (in WoW, five players) so they can fight mobs inside the instance privately, without being interrupted or helped by the players outside the group. The instanced part of the virtual world is replicated for each new group that enters it, so at any one time there can be any number of instances of a certain dungeon on a single server, depending on the number of groups. Other characteristics of the dungeons action type include dynamic player input rate, up to five players participating, rather limited overall mobility, and relatively large number of NPCs participating.

While most dungeons are designed for a group of five players, there are also instances designed for larger groups of players (i.e., 10, 25, or 40), called *raids*. In general terms, we refer to dungeons as a "small group activity", and to raiding as a "large group activity". Challenges for small and large groups in similar forms exist in most MMORPGs – for example, LOTRO has instances for small groups of six people, called *fellowships*, and raid instances for groups of two or more fellowships.

Raiding, as implied by name, is an activity performed by raids, and it typically involves engaging in battle with very challenging and complex mobs. Raiding characteristics differ from dungeons, in terms of group size (typically, larger groups of players and mobs are participating), higher rate of actions performed, and greater overall complexity. As the difficulty of the task increases, the rewards are higher – thus, in general, raids provide better quality items than dungeons, and dungeons' rewards are better than those obtained by questing. Raiding is one of the most complex tasks in a MMORPG, with very strict demands on players – not only on the required level to participate and the necessary equipment to perform certain tasks, but also on players' coordination and cooperation. As an example, we take a fight with *Lady Vashj* from first WoW expansion, *The Burning Crusade* (TBC). The fight requires a raid of 25 players which needs to be strictly organized, with special positioning requirements, and raid setup requirement, and be able to adapt to phases of the encounter, as described in the tactics guide [29]. In-game player organizations are called *guilds*. Most guilds use voice communication as a rule while raiding. Progression made while raiding is mostly in terms of equipment, but also through achievements which are publicly acknowledged on the server, thus adding up to a person's virtual "significance". Although

achievements do not change the power of the player's avatar, they have been shown to constitute a strong motivating factor for players' involvement in the virtual world. Ducheneaut, Yee, Nickell, et al. [30] offer the following explanation (on the purpose of audience in a MMORPG): "*It is not "the people that are addictive" but rather, "it's the image of myself I get from other people."*, in other words – achievements basically present a way to "showing off" one's virtual self to other players.

PvP combat is a very important element of a MMORPG, and most MMORPGs have ways to involve players in combat. The newly released game "Darkfall Online", by Aventurine SA, bases the whole game on PvP combat rather than *player versus environment* (PvE) encounters. In WoW, PvP combat is realized in three different ways. The first way is *world PvP*, in which players using the specific servers (PvP servers) can engage the members of an opposing faction in combat in most parts of the virtual world. In the last expansion *Wrath of the Lich King* (WotLK), a whole zone in the world was especially dedicated for world PvP. Secondly, there are also *Battlegrounds*, instanced battlefields in which groups of players (i.e., 10, 15, or 40 players) can fight other faction members in order to achieve specific goals (e.g., capture the flag, acquire a certain amount of points, or, kill an enemy general). The third type of PvP combat is *Arena combat* in which teams of two, three, or five players are engaged in instanced combat with each other. In this work we do not address *world PvP*, as world PvP combat can occur at any time and it is hard to predict or track, as opposed to battlegrounds and arenas for which players enlist when they wish to participate in one. In terms of complexity, PvP combat is one of the most complex action types in a MMORPG. The number of players can vary significantly. In a 2v2 arena matches there are only four players, while in some battlegrounds the number of players participating in action can (theoretically) be up to eighty. Coordination of players can also vary, as in arena tournaments the players can be in strictly coordinated teams, with voice communication as a must, while in some situations the players play "alone in a group" with no communication and coordination with other members of the team. A typical battleground team in WoW consists of randomly selected enlisted players, who have the same goals set by the game rules, but do not necessary work in coordination in order to achieve those goals. In PvP combat, the action rate is very dynamic, and the players are almost constantly on the move. The number of NPCs can vary, but the NPC activity is usually low as the focus in this action type is on (human) players. Progression is made through achievements and equipment, which players buy for honor and arena points (earned in battles in battlegrounds and arena, respectively). Being victorious in battles also increases the position of the player on the competitive ladder. While the specific types of PvP combat differ in different games, the key parameter is really a number of players involved. Further investigation of this category is out of scope of this article.

Questing is a player activity related to tasks (*quests*) assigned to players by the NPCs. Quests vary in nature and difficulty, but in general they always yield a certain reward in form of an item and experience points (e.g., a "mine warden" can ask the player to gather a certain

amount of ore, while the "mine guard" can ask him/her to kill the robbers which have taken residence inside the mine). Thus, questing is a major activity for most players – especially before they reach the maximum level – to gain experience, gold, equipment, and achievements, as well as to become familiar with the story of the game. Quests can be done in groups or by a player alone but, as indicated by Ducheneaut, Yee, Nickell, et al. [30], the players tend to play "alone together" and perform the tasks alone whenever the task is "doable" by one person. Questing can be performed together with other action types, as the goal of the quest may also require killing NPCs, venturing into dungeons in small groups, or even forming raids to beat the most formidable opponents. In order to isolate questing activities from other actions, we only consider the tasks which include one player acting alone, or a small group. Hence, the quests which include PvP combat, raids and dungeons have not been examined in this study. Characteristics of questing are mostly a small number of players participating (usually, up to 5), simple, repetitive, and not highly dynamic action rate with periods of low activity (just moving through the virtual world), and medium player mobility. The NPC count can vary significantly from one quest to another. As quests are relatively simple actions, they require a low level of player coordination and cooperation.
For the purposes of this paper, the player actions described above are broken down into five distinct categories, to be used for further analysis:

- Questing,
- Dungeons,
- Raiding,
- Trading and Professions related actions, and
- Player versus Player (PvP) combat.

With respect to our earlier proposed categorization [14], we now consider questing and dungeons as separate categories. (For the sake of conciseness, in the sequel we refer to "Trading and Professions related actions" as (just) Trading.) A star plot in Fig. 1 illustrates the proposed categories as related to the properties used for the description of player actions. Lower values are located towards the middle of the plot, while higher values are located towards the outside.

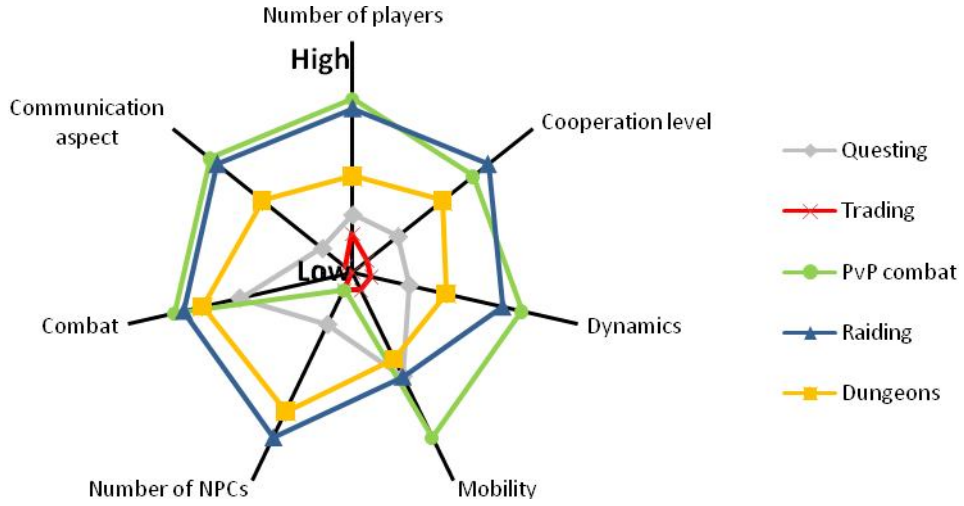

Fig. 1 Player actions categories

As shown in Fig. 1, the proposed action categories are distinct. There are similarities between PvP combat and raiding as those action categories have high values in number of players, cooperation, communication and dynamics. Still, they differ greatly in mobility and especially in number of NPCs. We can also note that shape of dungeons and raiding is similar, but that was expected as both categories are conceptually similar and mostly differ only in scale. Trading evidently differs from other categories.

3. Methodology for data collection and analysis

The features of interest include network traffic characteristics, session duration and player activity patterns, player interest, and latency requirements.

3.1. Network traffic characteristics

Network traffic characteristics of interest include packet size, packet interarrival and interdeparture time, bandwidth usage and packet load. (The packet interarrival time is the time interval between two subsequent incoming packets, and the packet interdeparture time is the time interval between two subsequent packets sent.) The above parameters have been selected based on their relevance for networking support for mobile gaming. Packet size affects the throughput and possible fragmentation over wireless links. The interarrival and interdeparture time are related to the dynamics of user actions, types of interaction, and the processing load on the game platform, as well as in the network protocol stack. Bandwidth usage and packet load both represent the amount of traffic sent and received, where bandwidth usage refers to the part of used network capacity, while the packed load also shows the amount of processing for sending and receiving packets. In aggregate traffic, there is also a correspondence to the number of users and NPCs.

Busse, Lamparter, Mauve, et al. [8] have also used most of these parameters for modeling their proposed QoS support for networked mobile gaming. The analysis of network traffic characteristics is based on collected data traces. The traces were collected at the client,

including the outgoing (client-generated), and the incoming (server-generated) traffic. In general, apart from the game owner, the Internet Service Provider (ISP) hosting the server, and the network operator, there is no easy (or perhaps even legal) way to collect traces on the server side. The annotated, player action specific network traces described here were acquired from six real WoW players (volunteers). The Wireshark software network protocol analyzer (http://www.wireshark.org/) was used to capture the incoming and the outgoing traffic on a client. The measurement procedure was as follows: as the player was about to do a specific action in the virtual world, he or she would start data capture with Wireshark. For dungeons, raids, and PvP combat, the player would start the capture upon entering the instance (e.g., raid "*Gruul's Lair*", dungeon "*Hellfire Citadel*", PvP battleground "*Arathi Basin*"), and stop the capture when leaving the instance. For questing, the players started the capture upon receiving the quest and stopped it once they finished all questing related actions (i.e., logging out, or setting out to do some other action). For trading related actions, the players were instructed to capture the session in which they tried to sell or buy something in the AH or from another player, including when checking in-game mail and/or bank for retrieving items. Finally, for professions, the players were instructed to start the capture before beginning to craft (at least ten items) and stop it as soon as they finish the crafting procedure. In the end, the players saved the trace into a file, and annotated it with a designation of what they did during that particular capture. It should be noted that the annotation followed the categorization, meaning that, if the player was basically raiding and during that time briefly crafted something (like, for example, a health potion), the trace was labeled "raiding". Or, to give another example, if a character was in dungeon and in the meanwhile completed a quest, the trace was labeled as "dungeons". The biggest problem with the measurement process was the players' immersion in the game – namely, the players often forgot to stop (as well as to start) the capture at the right moment, resulting in more than one type of player actions being represented in a given trace. As a result, a large portion of taken measurement data (additional 500 MB) was discarded and not taken into consideration. Players' designation of what actions they performed during the trace was used as an indicator of whether the trace is useful or not. A total amount of useful data, in terms of context specific network traces obtained in this way was 1.28 GB. This data was used for further analysis, presented in the next section. Interested parties may contact the first author to obtain this data (anonymized), free of charge for use in research and education, under certain agreed conditions.

3.2. Session characteristics duration and player activity within a session

The session characteristics of interest include overall session duration and player activity within a session. As for the session duration, we define it as the time interval between the time when the player logs in to his character and the time of the corresponding log-out from that character. The duration of a specific action within a session can be determined from the event log, within the bounds set by the log time granularity. Intuitively, the duration of an action corresponds to the time interval between consecutive changes of context from the

player's point of view. In the event log, this may be approximated as the time interval from the first event of the observed action type ($\underline{a_i}$) to the last event of that type ($\underline{a_i}$), with the next action type starting with the event ($\underline{a_j}$), etc., as illustrated in Fig. 2. The problem here is how to interpret the time in-between actions a_i and a_j, i.e., the time in-between the events ($\underline{a_i}$) and ($\underline{a_j}$), say t_{ij}. While it is obvious that this interval could be divided between a_1 and a_2 in many ways based on a precise recording and study of human behavior during play, this would obviously be out of the scope of this paper. For practical purposes, as well as taking into account the granularity of event log time (in case of WoW, it's 1 minute), we decided to keep things simple, and consider t_{ij} as a part of action a_j, assuming that the actual changes of context occurs once (or soon after) the player completes the last action in the sequence of actions of one type, in order to perform the next one. The error introduced by this assumption is limited by setting an "idle-time threshold" (t_{idle}) for the maximum time interval in-between two actions to 5 minutes. If the interval between action types in the log data was larger than the threshold, the user was considered inactive for that period of time, and this interval then was not taken as belonging to any action type. The 5 minutes' time was determined based on game rules, as after 5 minutes of inactivity the player is labeled as idle or Away From Keyboard (AFK). The argument above started from the premise that a_i and a_j are different action types. If a_i and a_j are actions of the same type, the following rule applies: if t_{ij} is less than 5 minutes, the corresponding time intervals are merged and labeled as belonging to the common action type; otherwise, that t_{ij} is labeled "idle".

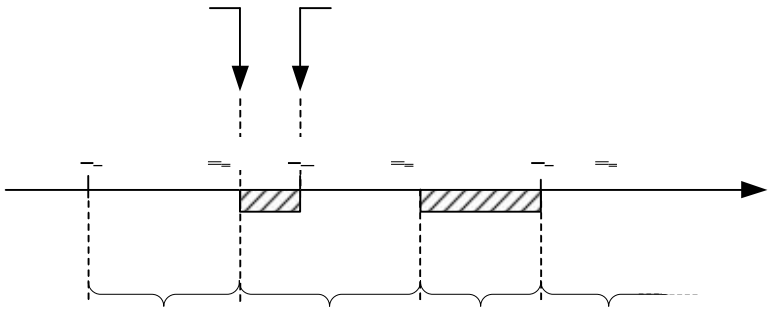

Fig. 2 Determining the duration of a specific action within a session

To be able to determine the session duration time and the times for specific types of player actions, we developed an add-on for WoW, named *WoW Session Activity Logger* (*WSA-Logger*). The *WSA-Logger* serves as a "recorder" of in-session events, by noting the date, time, and player action throughout the session. The add-on was developed by using Ace3 [31] and Blizzard Entertainment's WoW Application Programming Interface (API) [32]. The list

of all WoW API events is available [33] and the taxonomy of events therein enabled us to map the events onto our player action type categories, for example, the bank events to the *Trading* category; the battleground events to the *PvP combat* category, etc. The time granularity of the *WSA-Logger* is one minute, as rigidly determined by the WoW API (the means to record time is the *GetGameTime()* method, which returns the game time in hours and minutes).

The relationship between WoW API events and player action types was determined by using a decision tree, shown (simplified) in Fig. 3. For some actions, the decision is more complex, while for others it's rather simple like, for example, when the AUCTION_HOUSE_SHOW event is fired, once the auction interface (used for trading) is first displayed, the *WSA-Logger* notes the date, time, and player action type as "trading". All mail, bank, trade, and profession related events in the WoW API (e.g., TRADE_ACCEPT_UPDATE) are interpreted as "trading", all quest related events (e.g., QUEST_ACCEPT_CONFIRM) are interpreted as "questing", and all PvP related events, when it can be confirmed that the player is located in a battleground or in arena (e.g., UPDATE_BATTLEFIELD_SCORE), are logged as "PvP combat". Dungeons and raids are examined in a different way, by using the ZONE_CHANGED_NEW_AREA event, which is fired whenever a new zone is loaded (e.g., when the player enters or leaves an instance), and a list of names of all currently active dungeon and raid instances (as this event may also be fired in some other occasions). This helped determine the time interval which the player spent within the instance. If the player participates in several instances in a sequence, then the total time (combined) is taken into account. During the time spent in the instance, other events such as questing or trading were not taken into account.

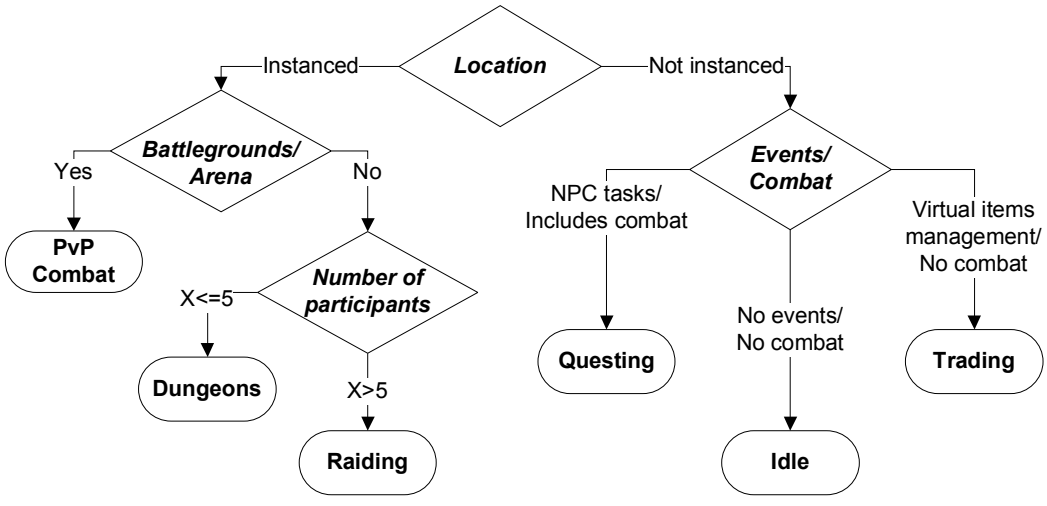

Fig. 3 Decision tree for action type determination (simplified)

The *WSA-Logger* was used to log the game play sessions of eleven WoW players (the initial six who created annotated traces, plus additional five volunteers), who installed the *WSA-Logger* on their PCs and used it for the period of about 6 weeks in November – December 2008.

3.3. User interest in playing on mobile platforms

To determine which of the action types player would most want on mobile phones, if such a possibility existed, we conducted a simple survey among players participating in the data collection and player population "at-large" – in-game on "Bladefist" EU realm and in WoW Europe forums.

3.4. Latency

In the latency analysis we propose a mapping of different action types into the precision-deadline plane by adopting a methodology introduced by Claypool and Claypool [24].

4. Results

The results obtained from network traces are shown first, followed by the results obtained from data collected by *WSA-Logger*, and finally those from the player survey.

4.1. Network traffic characteristics

4.1.1. Packet size

Fig. 4 shows the cumulative distribution function (CDF) of the payload size of the client generated traffic, where payload size corresponds to the application-layer protocol data unit (PDU) size. In general, the client payload size is very low which confirms the previous research results [9]. An average payload size across all action types is 36 bytes, which is less than the typical overhead of TCP/IP (40 bytes). The largest PDU size is for PvP related actions, the next (in the decreasing order) is for raiding, and the next for dungeons related actions. This confirms the hypothesis that client PDU size is proportional to the rate of the player input. Also, we observed several values of the client PDU size corresponding to specific action types. For example, raiding has a large number of packets with 19-byte PDUs, and questing and trading a large number of packets of 39-byte PDUs.

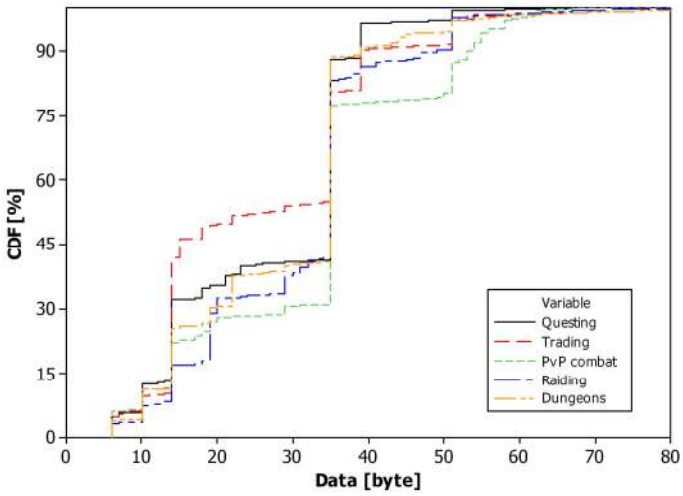

Fig. 4 CDF of outgoing (client generated) packets payload size

The server-generated payload size distribution is shown in Fig. 5, and it may be noted that it is much wider than that of the client. The average payload size varies from 163 bytes for

trading, up to 616 bytes for raiding. The amount of information sent by the server is highly dependent on the virtual world context, as the server may have to send a possibly large amount of data about a number of entities it controls (e.g., mobs in the raid environment).

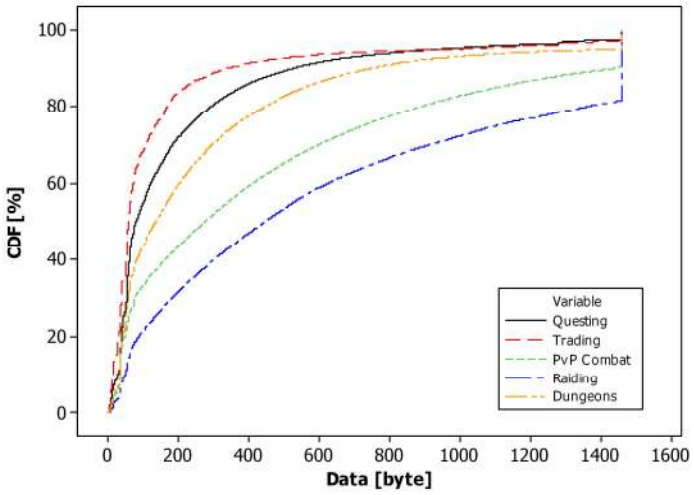

Fig. 5 CDF of incoming (server generated) packets payload size

Fig. 6 illustrates the percentage of data packets belonging to a particular action category in the overall data. The percentage of outgoing (client generated) data packets varies significantly, as PvP combat generates about the double the number of data packets (58%) compared to trading (23%). The incoming (server-generated) traffic has an average value of 76% data packets with a smaller variation than the client side, with the largest portion of PDUs sent for trading (86%), followed by all other categories.

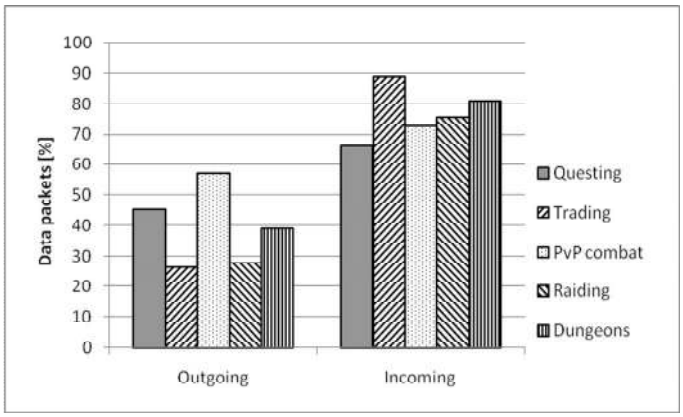

Fig. 6 Percentage of client data packets, per category

4.1.2. Bandwidth usage and packet load

As shown in Fig. 7, the bandwidth usage in WoW (most of the time under 10 kbit/s) is remarkably low. This is made possible by storing the most of the media-rich elements of the virtual world locally, i.e., on the client (note that the complete WoW installation takes up 12 GB of hard disc space). What needs to be sent over the network includes only updates with position/orientation and actions of the players' avatars, NPCs, and mobs. While this model

would be applicable to mobile devices as well, in practice it would have to be significantly scaled down since even the high-end mobile phones currently have up to 16 GB of space (and this being, usually, on external memory cards).

As shown in Fig. 7, PvP combat generates the largest load, and trading the smallest load on the network in outgoing direction. The incoming traffic shows more variation, as raiding uses six times more bandwidth than questing and trading. This is expected, since there is much more server-generated information to be sent during raiding, compared to other action types.

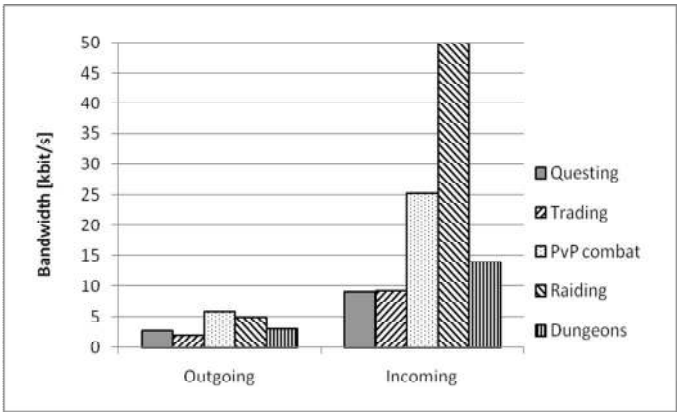

Fig. 7 Bandwidth usage, per category

As shown in Fig. 8, the overall packet load in number of sent packets per second is rather low, which confirms previous results [9, 12].

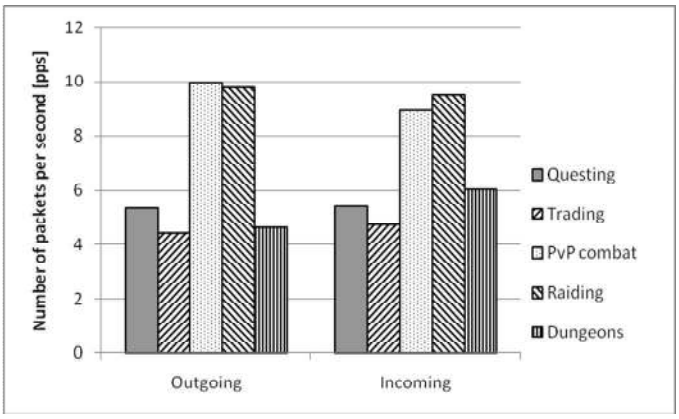

Fig. 8 Number of packets sent, per category

The average is 10 packets per second in both ways. The difference between the number of client generated and the server generated packets is minor, but the differences between particular actions are large. Most of the packets are sent during raiding and participating in PvP combat, whereas the amount of packets sent while trading is three times smaller. Traffic patterns in both cases are bursty, as shown in Fig. 9, which displays the traffic patterns of a character involved in a trading action (creating armors), and Fig. 10, which shows traffic patterns for PvP combat (arena match in 2v2 bracket).

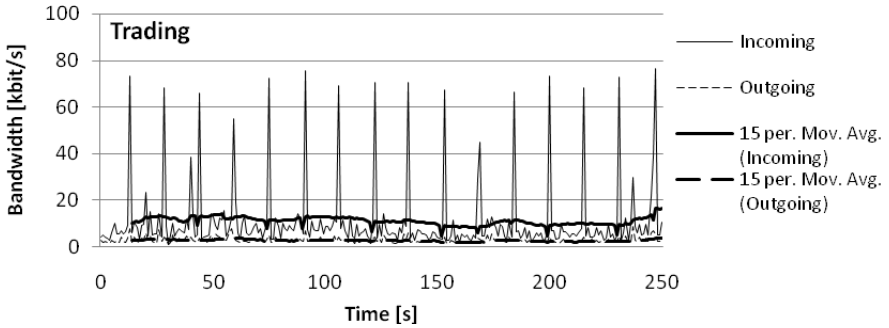

Fig. 9 Incoming and outgoing traffic time series (trading)

In relative terms, the client traffic bandwidth requirements clearly differ, PvP being higher than trading. Further on, in Fig. 10, three distinctive patterns can be observed: a) a fairly "quiet" interval in the beginning while the teams are preparing for battle (i.e., first 60 seconds in the trace), b) the increased activity while teams examine each other (i.e., from 60 to 90 seconds), c) the actual battle (90 seconds and after) with high activity and visibly higher bandwidth requirements.

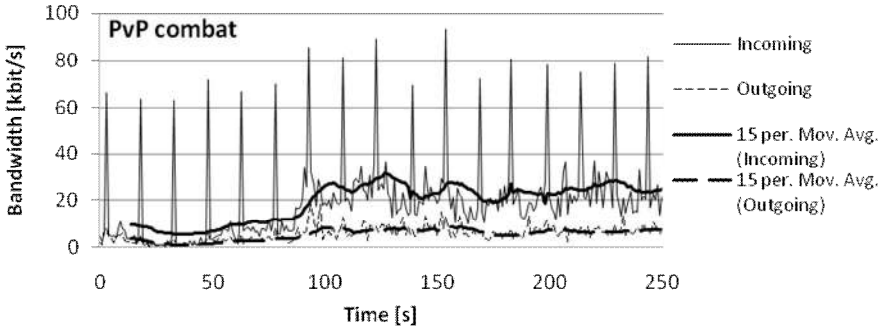

Fig. 10 Incoming and outgoing traffic time series (PvP combat)

4.1.3. Inter-departure and inter-arrival times

As Fig. 11 shows, inter-departure times are inversely related to the game action pace: the faster the action, the lower the inter-departure time. PvP combat with highest required input rate has the shortest inter-departure times (50% mark is around 0.05 seconds), followed by raiding, dungeons, and questing in the middle, and trading with longest inter-departure times (50% mark is around 0.21 seconds). It may also be noted that 5% of the updates generated by the client in the trading category have inter-departure times greater than 1 second.

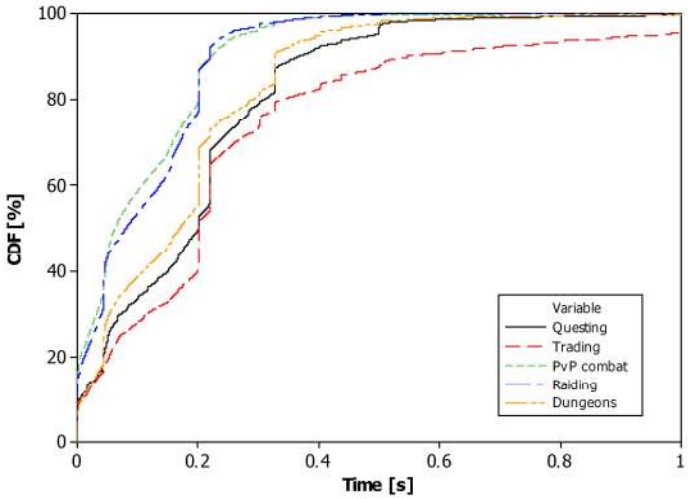

Fig. 11 CDF of client's packets interdeparture times

Almost 50% of all packets in all categories except questing have inter-arrival times less than 0.1 second, as shown in Fig. 12. This can be explained by the reduced need (and, hence, frequency) for sending updates for other players' position in questing and dungeons categories (players usually quest alone, and dungeons are limited to five simultaneous players). It seems likely that WoW client software autonomously controls the mobs and NPCs for a while without server side updates (applying the principle known as *dead reckoning*), thus resulting in fewer updates.

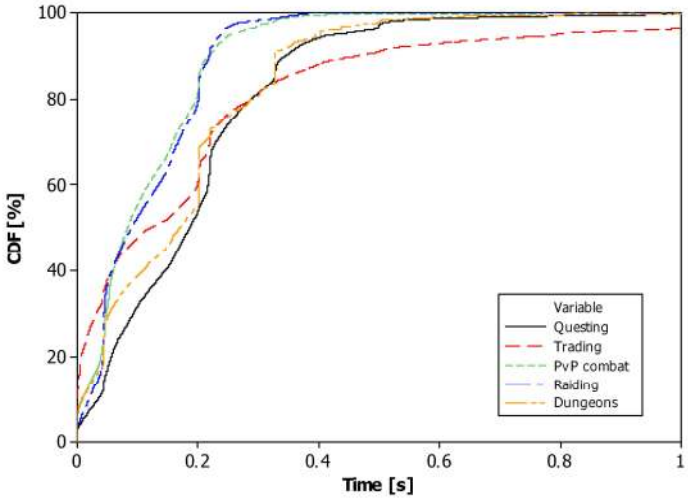

Fig. 12 CDF of server's packets interarrival times

4.2. Session duration

From the data gathered with *WSA-Logger*, we extracted the values for the session duration time, and the durations of particular action types within the session. The relevance of this data for designing mobile MMO is related to the fact that mobile gaming sessions, in general, tend to be short [34].

Fig. 13 shows the CDF of session duration. The acquired data consists of 2753 individual game play sessions. The mean session duration value is 54.92 minutes. Interestingly, about 24% of sessions lasted 2 minutes or less, while the longest session lasted almost 10 hours (598 minutes). A high percentage of short sessions can be explained by phenomenon of *alts* (alt[ernative]s, or "secondary" characters) and their usage. Many players have one or more *alts* and use them as an extension of the main character's capacity to store game items. Alts are also used for additional professions, due to the inherent limitation of the game which allows one character to learn at most two main professions (e.g., the main character can be alchemist/herbalist, while the alt can be a leatherworker/skinner).

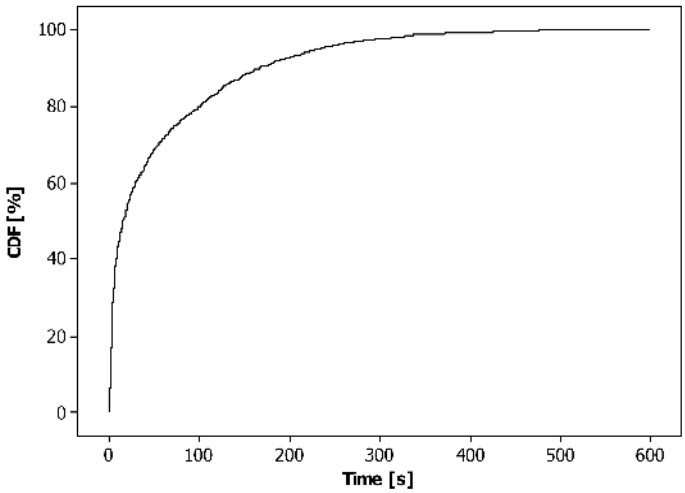

Fig. 13 CDF of session duration

Fig. 14 illustrates how much time players spent performing a particular action type, or in other words how "popular" a particular action type is. In this particular trace, the most popular activity (by far!) is questing. This, however, is an atypical case, for a simple reason which became evident later: our measurements were taken over the six weeks in November – December 2008 following the release of the new expansion for WoW (*Wrath of the Lich King*, on 13th November 2008). With the players eager to reach the required level for "high end" game play participation (raiding, dungeons, and rated arena combat), questing provided them with the most efficient means to achieve it. In this trace, dungeons are the second most popular activity. It is interesting to observe how the share of questing in overall session time decreases over the time period when the measurements were taken, as shown in Fig. 15. It may be noted that, as time passes and more players reach the maximum level, the share of questing is being reduced. Further on, there is a huge increase in PvP combat activity around the 16th December, the date when another battle arena (*Arena season 5*) started. These results indicate a high interdependence of action type "popularity" and in-game conditions.

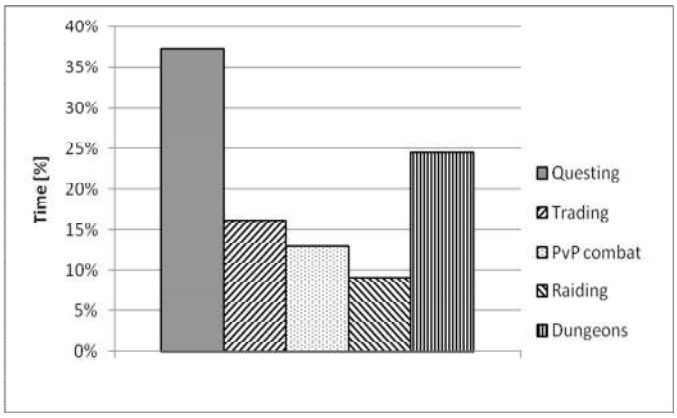

Fig. 14 Percentage of time spent playing, per category

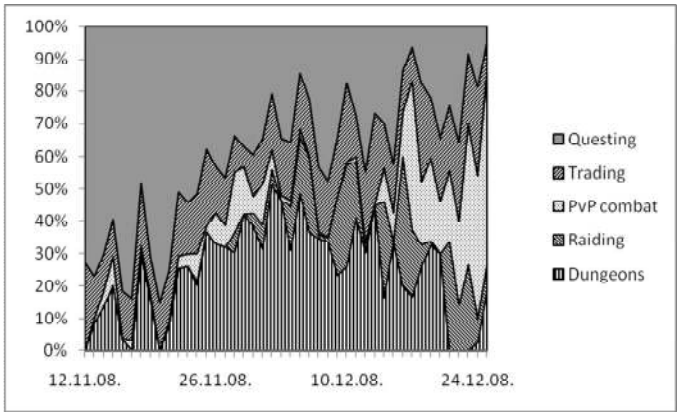

Fig. 15 Proportion of action categories (trace dating from Nov. – Dec. 2008)

Fig. 16 breaks the amount of time per action per player. While there are evident similarities between some players, there are also significant differences (e.g., some have not engaged in PvP combat at all (3, 6, 7), while some others did a very few dungeons (1, 7, 9)). Classification of player psychology and behavior is outside of scope of this work.

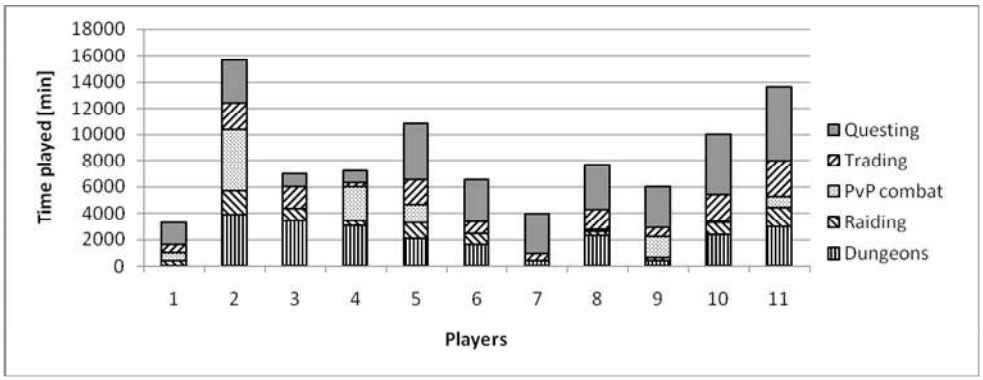

Fig. 16 Amount of time spent playing, per category, per player

The session length per specific action type was also analyzed in order to find out which action type(s) may be most appropriate for implementation in a game version suitable for mobile devices. The results are summarized in Fig. 17. It may be noted that all action types have lengths of sessions varying from very short to rather long. On average (as well as intuitively),

trading requires shortest sessions. Dungeons and raids are activities that, in general, require longer sessions, followed by PvP combat and questing. Questing sessions are, on average, rather short.

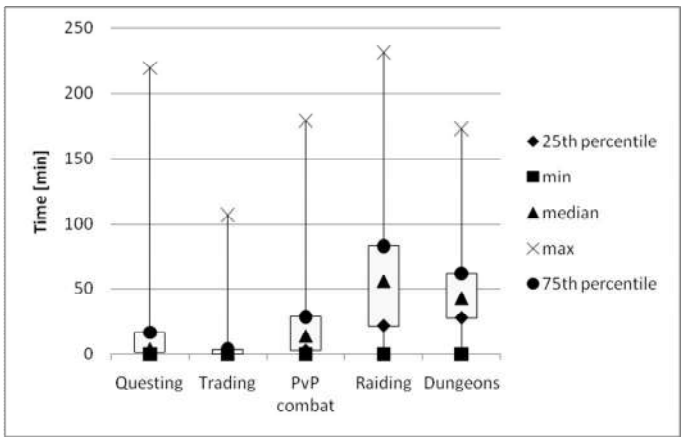

Fig. 17 Statistics of time length for particular player actions

The CDF for session duration broken up by action types is shown in Fig. 18. The shortest session duration is for trading, which has 90% of the sessions below the 20-minute mark (the average length of a gaming session on a mobile phone [34]). Based on session length, possibly acceptable actions would also include questing and PvP combat. Dungeons and especially raiding seem too long for mobile sessions (e.g., raiding has the longest average session duration of 63 minutes).

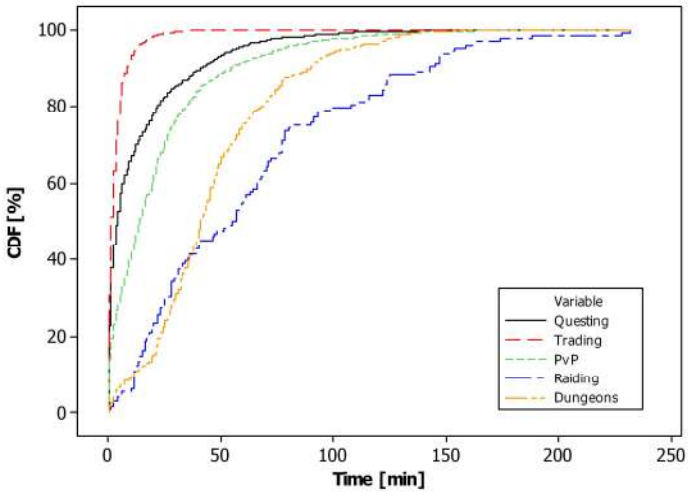

Fig. 18 CDF of action specific session duration

4.3. Player survey

To examine player interest in specific action type, an informal survey was conducted in-game, in forums, and with the players who participated in measurements. The players were asked the following question:

If your mobile phone could be used to play WoW, what type of action (Questing, Dungeons, Trading and professions, Raiding, PvP combat) would you most likely use it for? (More than one answer is acceptable.)

Optionally, they could also write-in other preferred game activities and comments. A total of 63 players participated in the survey. The results are summarized in Fig. 19. Trading was by far the "most wished for" activity (more than 50% of participants), and interest for all other activities was lower (10-15% of the participants). Raiding was the category which never occurred as a single preference by the players, it only occurred among players who stated they want to do all categories.

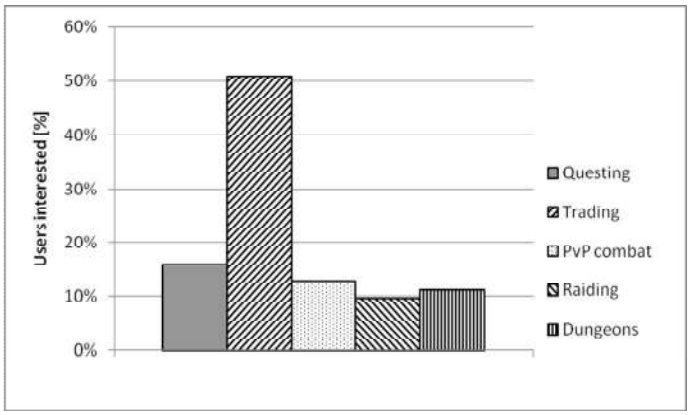

Fig. 19 Player interest in performing specific action type on a mobile phone

An interesting point was that under "other activities", several users expressed high interest in the personal communication aspects (i.e., in-game chat client, which was not offered as an option in the questionnaire), which confirms the claims stated in [19]. Some other interesting suggestions include:

- *I'd definitely use it to log my bank character on and to collect money, to auction items or to distribute stored items to my various other characters...*
- *I'd probably also use it to craft items with my characters (well, making things with cooldowns)*. [Note: *cooldowns* are items with time cap on item production.]
- *Social; Give me a chat client with /g /2 etc :)* [Note: reference to specific chat groups.]
- *I would probably use such a feature mainly for chatting. For instance a scenario where I want to do a 5-man instance - I then log onto my phone to chat and find a nice group, and then I log on and start the instance on my PC.*

While these results and comments may not be representative for the overall gaming population due to a small sample size, they indicate that it is not necessary to wait until the mobile phone capabilities become comparable to PCs in terms of capabilities – for some types of player actions, a MMORPG variant based on carefully selected functionality adapted to mobile phones may be available even sooner.

4.4. *Latency requirements*

The effects of latency measurements and requirements for MMORPGs have been studied by Fritsch, Ritter, and Schiller [22]. The extension made in this work is to map our defined action categories onto a *precision/deadline plane*, by adopting the methodology proposed by Claypool and Claypool [24], briefly descried next. The precision/deadline plane allows the actions in the game to be categorized according to two key attributes, or axes: 1) the accuracy required to complete an action successfully (referred to as *precision*), and 2) the time required to achieve the final outcome of the action (referred to as *deadline*). In the context of the above categorization, precision and deadline are considered as qualitative, rather than quantitative measures. "Higher precision" means that the player, in order to do something, needs to perform it strictly as planned (with high spatial accuracy), or else the outcome would not be successful. "Lower precision", of course, is the opposite. "Tighter deadline" means that the player has less time to perform the action in order to be successful, while "looser deadline" is the opposite. Considered together, these attributes describe the effects of latency on the action. In general, the latency requirements for actions with higher precision and tighter deadlines are the most difficult to meet, while for other combinations the requirements may be relaxed in some respect or other.

Related to precision in WoW, most of the *abilities* (i.e., in-game commands) use target selection, so spatial distribution of opponents is not so important. Once a player selects the object onto which to apply certain ability (e.g., select a mob to "kill"), he or she cannot miss. There also abilities which do not use target selection mechanisms, like *area of attack* (AOE) *abilities*, which by nature do not require high precision. The precision in WoW can be reduced to the task of selecting the right target. This is trivial while trading, because players engaged are stationary as well as the NPCs involved. The complexity rises somewhat in the questing category, where targets may be mobile, but more often than not they are stationary. Raiding has higher requirements, where typically there is a high number of players and NPCs involved, and the situation can became a bit "chaotic". PvP combat has the highest precision demands because of the players' constant movement, the possibly large number of players, and also because of various evasion maneuvers (e.g., running behind an obstacle).

The deadline axis represents the timeliness in which specific action has to be completed. While trading, players can slowly browse auctions while searching for a best deal. In questing there is also little timeliness needed. Raiding has much tighter deadline requirements, as encounters in raids are designed to keep the players "on their toes", and each player has to perform his or her role in a timely fashion (e.g., if a healer is more than few seconds late, his charge will most likely die). The tightest deadlines are in PvP combat, as player reactions are unpredictable and sometimes a few hundreds of milliseconds can mean a difference between a victory and defeat. Fig. 20 illustrates the proposed positioning of MMORPG/WoW action types in precision/deadline plane. In future work we aim to address the relationship between latency and jitter (for mobile connections) on one side, and precision in the game on another,

in order to establish the thresholds beyond which significant performance degradation happens for a particular action type.

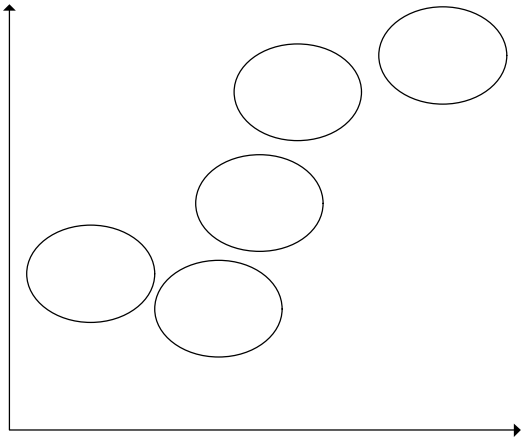

Fig. 20 Action types in precision-deadline plane

5. Summary and Conclusion

The summary of our findings regarding possible implementation on mobile phones, based on the discussion on network requirements, session characteristics, and user survey are illustrated in Table 1.

Table 1 Summary of recommendations for mobile MMORPGs

Action category	Feasible
Questing	Yes
Dungeons	No
Raiding	No
Trading	Yes
PvP combat	Maybe (modifications needed)

The findings related to networking requirements for different player action types are as follows: Trading has the lowest requirements in almost all network characteristics, while PvP combat and raiding showed as the most demanding activities on client outgoing (uplink) and client incoming (downlink) directions, respectively. Having the network limitations in mind, trading and questing categories would be the most suitable for possible implementation on mobile phone MMORPG application, though we must keep in mind that, in terms of bandwidth, a 3G network could support all of the action types, with only foreseeable problem being with action types with tight deadlines (i.e., low latency), such as PvP combat and raiding.

Session duration measurements showed that the players spend most of their time questing, followed by dungeons and trading. The distribution of action types showed strict time dependencies related to adding new content into the game. With regard to session time,

trading is the most suitable type for mobile gaming (shortest sessions), followed by questing and PvP combat. The players participating in our survey expressed a high interest in mobile access to trading, followed by questing and PvP combat. Players also stressed the importance of communication with their in-game friends.

In the latency analysis, we mapped our action types onto deadline-precision plane. The highest (relative) latency independence was showed by trading and questing category while PvP combat proved to have the highest demands. Based on measurements and analysis we conclude that trading capabilities would be the first to include in the gaming client for mobile phone. One possible way of how this could be done would be to implement only major cities into the game client (which would also significantly reduce the size of game client memory footprint, thus making it more suitable for mobile phones) and allow players to have access to a bank, a guild bank, an auction house, and various professions.

Implementation of questing could be a second step (though this could lead into implementing a whole virtual world, thus highly increasing the client software size), whilst for implementing PvP combat, the application would have to go through some radical changes, mostly due to the input and latency requirements. Implementing PvP combat in other ways, such as in a role of a tactical advisor on a battlefield, was previously suggested [20], and may present a viable approach. Dungeons and raiding would not be recommendable on the current state-of-the-art mobile phones.

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