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Transition-enabled Event Dissemination for Pervasive Mobile Multiplayer Games

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***Abstract*—Today's smartphones feature sophisticated computational capabilities as well as a plethora of sensors, enabling new kinds of applications. One popular example are pervasive mobile multiplayer games, where interactions with other users or physical objects in the real world are part of the gameplay. This induces a notion of locality, as a user's actions affect other nearby users. However, this locality in the interaction is not reflected in the underlying communication system. Events triggered by users are sent via the cellular connection to a remote data center, where they are processed and then distributed to other players, again via the cellular link. In this work, we demonstrate an event dissemination system that utilizes the available local communication interfaces of today's smartphones to distribute events in groups of nearby players. The system executes transitions between different communication interfaces (e.g., Bluetooth or Wi-Fi Direct) and the utilized dissemination protocol depending on the size and density of the group of players, thereby exploiting the characteristics of the chosen interface. Attendees can experience the resulting benefits in terms of latency and update frequency by playing our mobile pervasive multiplayer game TOWERWORLD at the venue.**

I. INTRODUCTION

Modern smartphones enable completely new applications due to their increasing computational capabilities and the sensors they offer to developers. One prominent example is the use of a user's location in mobile applications – be it to retrieve the schedule of a nearby bus stop or the best restaurants nearby. *Pervasive games* take this concept one step further by intertwining the user's current physical surroundings with the actual gameplay. Instead of controlling the game solely through the device's screen, users need to move around in the real world and interact with other users and physical objects.

From a communication perspective, a player's interactions and movement triggers events that are to be distributed to other affected players. As the gameplay in a mobile pervasive multiplayer game is mostly determined by a user's close vicinity, a large fraction of these events are distributed to nearby players, leading to a correlation between the locality of content and interest in the content [1]. However, this locality property is not utilized in the communication system, as events are sent to a datacenter for further processing. As users are moving around outside, the cellular connection is the predominant way to communicate with the datacenter. Despite wider deployment of 4G networks, the cellular connection still limits the achievable update frequency and induces additional latencies. These limitations are not solely technical: commonly, data tariffs are capped, thereby prohibiting extensive usage in applications. However, mobile devices are equipped with other communication interfaces, for example Bluetooth and Wi-Fi Direct, that are utilized in our demonstration to augment the cloud-based event dissemination. Our demonstration shows the benefits of the transition-enabled event dissemination system BYPASS [3] in the scenario of the mobile pervasive multiplayer game TOWERWORLD [2]. By activating local dissemination of events via Bluetooth or Wi-Fi Direct, game events are distributed to nearby players at higher frequencies and with decreased latency, enabling more interactive gameplay concepts. Depending on the size of groups and the proximity of players, BYPASS executes transitions between different dissemination protocols as well as the utilized physical technology during runtime. Thereby, the system benefits from the performance/cost trade-offs of the respective configurations.

Attendees can interact with the game and trigger transitions in the event dissemination system by approaching other players. To allow full gameplay during the demonstration (e.g., indoors and without the need to walk long distances), the position data required by the game is induced by scanning NFC tags on a map. Actual communication via Bluetooth or Wi-Fi Direct takes place between devices that are within close proximity according to their (virtual) positions in our demonstration setup. In addition to using the provided smartphones, interested attendees can download the application onto their own smartphones[1] directly at the venue to further experiment with the demonstrator.

The game TOWERWORLD is briefly introduced in Section II, followed by an overview of the transition-enabled event dissemination system BYPASS in Section III. Finally, the demonstrator scenario and its setup as well as the ways of interacting with the demo are described in detail in Section IV.

II. THE TOWERWORLD PERVASIVE GAME

In this demonstration, we utilize the mobile augmented reality multiplayer game TOWERWORLD [2] as one application for our transition-enabled event dissemination system. The game is inspired by Google's Ingress[2], in that players interact with specific points of interest, called *energy sources*. In contrast to Ingress, TOWERWORLD focuses on direct interaction between players, thereby enabling a more interactive gameplay. This, in turn, requires higher update frequencies of events as well as lower latency for their delivery to ensure smooth gameplay. In the following, the core game mechanics

[1] Requires a recent Android device (Nexus 5 is recommended).
[2] www.ingress.com

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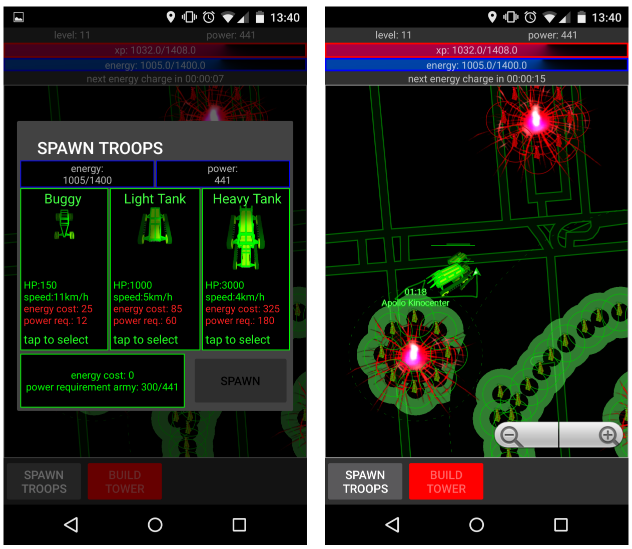
relevant for the demonstration are briefly described. For an in-depth description of the game, the reader is referred to [2].

Objective of the game is to conquer energy sources by attacking the surrounding protective towers. In order to attack towers, players have to spawn units that follow the player's movements (c.f. Fig. 1a). If a player moves into the attack range of a tower, his units start attacking the tower. To increase the chance of conquering an energy source, players can form groups with other nearby players and jointly attack the towers of other groups or players. Points obtained from conquered energy sources are required to spawn new units or to build protective towers around energy sources.



(a) Spawn new units.

(b) Points of interest and towers.

Fig. 1. Screenshots of the TOWERWORLD pervasive game, showing the player's current position, its units, towers and in-game points of interest as well as the menu for spawning new units to conquer towers.

The main screen of the game (c.f. Fig. 1b) shows a map of the current vicinity of the player as well as the player's current position and its units. Additionally, players of the same group and their units are shown on the map as well, allowing players to coordinate their gameplay within the group. Lastly, energy sources and towers are depicted on the map. The game follows the player's movement in the real world by obtaining regular position updates via GPS. As groups of players need to collaborate to conquer new energy sources, the game displays actions of players on each group member's mobile device. Transmitting events via the cellular link introduces additional delay and limits the update frequency (due to constrained data tariffs). This limits the perceived smoothness of the game and thereby affects the user-perceived quality. To address these limitations, the transition-enabled event dissemination system BYPASS [3] is utilized as communication middleware for TOWERWORLD, as described in the following section.

III. TRANSITION-ENABLED EVENT DISSEMINATION

To distribute events in-between players, the transition-enabled event dissemination system BYPASS [3] is showcased in this demonstration. Relying on the SIMONSTRATOR platform [4], the simulation model presented in [3] can be deployed on Android devices without alterations to the code. Some peculiarities of the SIMONSTRATOR w.r.t. handling GPS locations in our demonstration setup are discussed in Section IV. The core idea behind BYPASS is the execution of transitions between different local dissemination protocols depending on the density and group size of nearby players as illustrated in Figure 2. Rationale behind this is the observation that local dissemination protocols exhibit different performance vs. cost trade-offs depending on the current environmental conditions. By augmenting the cellular delivery of events with direct communication between nearby players depending on the group size and density, the latency of event delivery is decreased, leading to a more fluent gameplay. Still, the connection to the cloud is maintained for events that require consistent processing (e.g., events that affect the global state of the application). Event delivery via the cloud ensures that this class of events is received by each interested party *at least once*. The application has to take care of maintaining order and consistency, in case the events arrives multiple times. Events that only affect nearby players and do not have any impact on the global application state (e.g., events used for updating visuals) can be delivered solely via the local communication interfaces, thereby relying on a *best effort* service. The transitions between dissemination protocols are coordinated by the central server, as information about the users' locations is already available there.

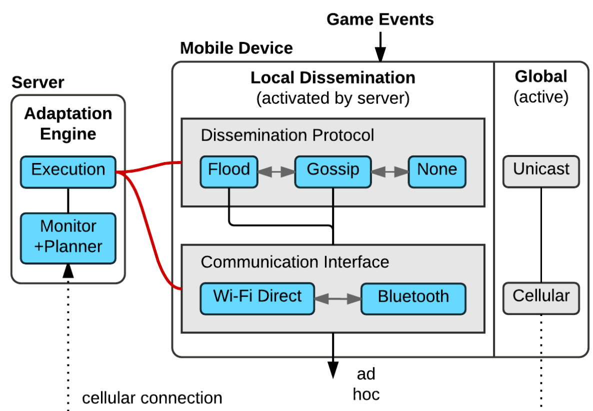


Fig. 2. Overview of BYPASS and the possible transitions at mobile devices, coordinated by the central server. If local event dissemination is enabled for groups of nearby players, the system can switch between different dissemination protocols and communication interfaces.

In addition to the dissemination protocol, BYPASS is able to switch between different physical transmission technologies available on today's smartphones (e.g., Bluetooth or Wi-Fi Direct). The decision which interface to use is based on the density of nearby players and their distance. Assessing the trade-offs of both interfaces under real-world conditions is part of our ongoing prototypical measurements, relying on an instrumented version of this demonstration. Commonly neglected peculiarities when it comes to local ad hoc communication includes setup times for enabling or disabling the wireless interfaces or constraints such as pairing procedures requiring manual user input. By assessing these constraints prototypically and feeding the results back into our simulation models, we aim to gain a deeper understanding on the cost and utility of a given transition in the system.

IV. Demonstration Scenario and Setup

The demonstrator showcases the transition-enabled event dissemination system Bypass [3] being used as communication middleware by the pervasive mobile multiplayer game TowerWorld [2]. Attendees can interact with the game and other players through a number of mobile devices (Nexus 5 smartphones). As the gameplay is heavily based on players' movements in the real world, a demo mode is enabled where fake location data is fed to the devices. To this end, a printed map of an arbitrary city is equipped with a number of NFC tags that carry the respective GPS coordinates, as illustrated in Figure 3. By scanning such a tag, the respective device moves towards the tag's location, following an arbitrary movement model. We refer to the given location on the map as the *virtual position* of a device.

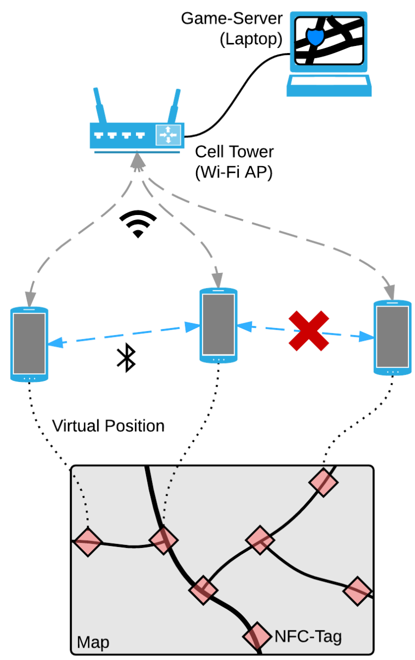


Fig. 3. Schematic overview of the demonstration. Players communicate via Wi-Fi with the central game server running on a laptop. They move to new virtual positions by scanning NFC-tags on a map of an arbitrary city. Once devices are in communication range according to their virtual position, they execute a transition and exchange events locally via Bluetooth.

While positioning in our setup does not rely on the GPS interface of the device, communication between devices uses the physical Bluetooth interfaces. To prevent devices from receiving messages that they are not supposed to receive according to their virtual position, messages sent by devices that are not within an assumed communication range are dropped transparently for the application within the Simonstrator platform, as illustrated in Figure 4. This enables attendees to experiment with the pervasive game TowerWorld and the transition-enabled event dissemination system Bypass without actually moving around outdoors. To be independent of the cellular connection, we provide connectivity to the central game server via a Wi-Fi access point (cf. Fig. 3). The central game server (i.e., the cloud) is represented by a laptop running the server component of the game and the communication middleware. All means taken in our setup to scale the scenario are transparent to the game and the communication middleware, ensuring full gameplay.

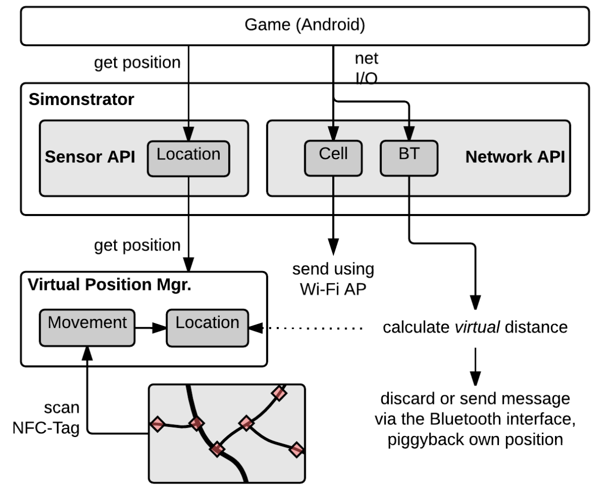


Fig. 4. Location handling in the demonstrator version of the Simonstrator platform. Calls to the location sensor are handled by the virtual position manager based on the scanned NFC tags and a movement model. Locally sent messages are discarded, if the distance between sender and receiver are higher than the assumed communication range.

If multiple devices are located within close proximity, Bypass activates local dissemination of events via Bluetooth. Once local dissemination is activated, the respective devices benefit from significantly reduced dissemination delay of events (i.e., faster updates of other players' actions). For the respective players, the perceived quality of the game increases, as other player's actions are visualized fluently and with negligible delay. By scanning NFC-tags on the map, attendees can move in the game, build and attack towers and interact with other nearby players. Depending on the position of devices, transitions in Bypass are executed and influence the perceived quality of the gameplay. Interested attendees can download a copy of the software to their Android phones on-site, enabling an even higher degree of direct interaction with the demo.

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