Internet of Things Based Multiplayer Pervasive Games: An Architectural Analysis

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Abstract. Recent advances, increasing affordability and popularity of Internet of Things (IoT) technologies are opening exciting new ways of interaction and sensing for mobile device users. Furthermore, the great acceptance of smart mobile devices in our daily lives makes possible various ludic experiences, which could be greatly improved with IoT technologies. This new setting opens many opportunities for design and development of Pervasive Games for the IoT. In this work, we propose a palette of canonic interaction models and gamification tactics that can be combined for the design of new Pervasive IoT Game experiences. Subsequently, we present the methodology and results of a validation interview regarding our model with experienced game designers. Finally, we present a case study for a Pervasive IoT Game, also giving an overview of our middleware for mobile communication as well as its extension for IoT, discussing the possibilities of implementing new Pervasive IoT Games using it.

Keywords: Pervasive games · Internet of things · Gamification · Middleware · Mobile · Collaborative · Multiplayer · Sensor tracking · Location based services · Sensing

1 Introduction

The recent emergence and increased deployment of Internet of Things (IoT) technologies are opening new avenues of research and development opportunities in Pervasive Games design. According to Gartner Group [1], IoT is "the network of physical objects that contains embedded technology to communicate and sense or interact with the objects' internal state or the external environment." One example of such IoT-enabling technology is Bluetooth® Smart (Bluetooth 4.0), which is rapidly expanding in the smartphone segment.[1] Nowadays, smartphones running the latest Android version, iPhones, Windows phones and Blackberry phones already support Bluetooth® Smart. In parallel, many companies are designing and producing several sorts of peripheral devices such as toys, watches, tennis shoes, heart-rate monitors and SensorTags[2] that are able to connect to Bluetooth® Smart Ready mobile phones.

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1 List of devices as of August-2014 at: http://www.bluetooth.com/Pages/Bluetooth-Smart-Devices.aspx.
2 Texas Instruments, CC2541 Sensor Tags, April 2013. More information at: http://www.ti.com/lit/ml/swru324b/swru324b.pdf.

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Therefore, very soon, many applications will revolve around the interaction with smart things, and games will be no exception. In fact, we envision that in the near future a huge variety of everyday objects, including toys, appliances, tools and other portable gadgets, will become *smart* and *connected* and will be silently incorporated on our daily lives and on our entertainment.

The referred smart objects usually feature some short-range wireless communication capability, as well as some limited processing and/or storage capability. Several of these objects will also have some embedded sensors (e.g., proximity, temperature, sound, light, acceleration, etc.) which will enable the objects to "sense and figure out what is happening in their environment".

Most importantly, these objects will be primarily low-energy, small, light-weight, and hence long-lived and portable. These last characteristics will lead, in our opinion, to an increasing incorporation of these smart objects as central elements in next-generation *Pervasive Games*, that is, games in which the traditional boundaries bestowed by traditional computer games are expanded in the social, temporal and spatial dimensions [2].

The era in which Pervasive and Mixed Reality Games will be part of our daily lives is already starting [3], and with these new technologies, the gameplay possibilities can be extended even further. Also, the increasing usage of *smartphones*[3] is a positive setting for a future in which *smart personal devices* can interact with *smart things*. In fact, we think that smart things and smartphones will be used *together* in future Pervasive IoT Games, where the latter will function as the player's window to the cyber-physical gameplay.

2 Towards Designing Pervasive IoT Games

We open the discussion with the question: *Should Pervasive IoT game design be significantly different from current mobile game design?* This is relevant because we are handling new and not widely tested (marketwise) technology. To answer that, it is interesting to separate two important concepts of game design: the *Base Interaction Model*, which is directly related to the gameplay mechanics, and the *Gamification Tactics*, which are tools and strategies to hold the attention of the player and immerse him onto the experience, thus transforming the player interaction into a proper game.

For the rest of this section, we propose a *model* for designing Pervasive IoT games through separation of the core elements of the game experience. We have to acknowledge the contribution, as base inspiration for this model, the works of [4–8]. The model was validated through a qualitative interview described in Sect. 3 of this work.

2.1 Interaction Models

As it would be in a mobile game played nowadays, or in any other console or computer game by all means, there are base interaction models that are combined to give a certain

[3] According to eMarketer: http://www.emarketer.com/Article/Smartphone-Users-Worldwide-Will-Total-175-Billion-2014/1010536.

gameplay experience to the player. The player could control a character in a tri-dimensional scenario using keyboard and mouse, or a controller, for instance. The player could also interact directly to a screen with his hands and control a certain object, or draw a certain pattern. These are all base interaction strategies that are applied, and combined many times, to give the player a more complex way to interact with the game and have a certain experience envisioned by the designer.

These interactions can differ deeply from each other depending on the category of the game being analyzed. During this work, we use several definitions regarding these game categories that are defined in our *Game Design and Interaction Analysis*, accessible at http://www.lac-rio.com/projects/pervasive-iot-games.

Below, we present a few of the interaction models we identified as possible for future IoT Pervasive Games using smart tokens as sensors/things, those of which are capable only of announcing their presence/proximity:

1. Find the Thing (e.g. Mobile Geocaching Game)
Tokens: Fixed or movable
Main Idea: Users search for smart tokens. When a certain token is found, this action is registered on the user's smart device and/or a cloud service (if the game is multiplayer). A user can also pick up a token and bring it somewhere else or do a certain action with it. If the token is being moved, its coordinates could be updated to the cloud service by the user's smart device's own GPS. The user's interaction with the token directly influences the type of gameplay a game with this base interaction might have.

2. Guess where Things will be (e.g. Radar Tag Game)
Tokens: Movable
Main Idea: Tokens are always on the move. Tokens could be owned by certain users or be entirely independent. Players might need to guess a pattern of movement or discern the tokens next position/destination. Players could interact with the tokens when around them in a way to facilitate this movement prediction.

3. Bring lonely Things together (e.g. Smart Tag Game)
Tokens: Movable
Main Idea: Tokens are owned by certain users. In certain moments of the game, some users might be required to match their tokens with another token, which might be in possession of another player. This other player might be required to match his token with this same user, or the contrary, he could have to avoid this user for a certain period of time. These play mechanics will of course vary depending of the real proposition of the game.

4. Things that color other Things (e.g. Zombie Infection or Area Control Game)
Tokens: Fixed or Movable
Main Idea: Tokens are emitters of a certain type of frequency/data. When a player with a smart device and/or a movable token enters the actuation diameter of said emitter, the player is then "colored" or "infected" and is now visible to the game as a player of a certain type/color. The player could now act as a movable emitter to other players or fixed tokens. This type of interaction could lead to interesting tag/area

control games, dealing with other gameplay mechanics such as map/area strategy on an urban area and teamwork.

5. Change the Thing
Tokens: Fixed or Movable
Main Idea: When the player interacts with the token, it writes certain data on it. From then on, the token may behave differently than before, or start broadcasting a different type of data.

2.2 Gamification Tactics for Pervasive Games

For this work, we define *Gamification Tactics* as features that are capable of transforming an otherwise common action, task or interaction with a game element into an enjoyable ludic activity. This definition is used normally for non-gaming contexts [9], but we will maintain it for this work since the main idea still is *to "gamify" an otherwise non-ludic interactive experience*.

The employed tactics normally are what differentiates a successful game from a failure. Some of them are meta-game features, which means that they add to the game experience although they act directly from other features of the same game (e.g. game achievements). Some of them are:

- *Improve Certain User Perks when the Player is Doing Well*. Each time a user guesses right, the user gets gameplay points to increase his/her radar cell diameter, or else, use more radar cells to better surround the token [e.g. *"Guess were Things will be"*].
- *Achievements:* Each time the user accomplishes a hard task or passes a specific milestone in the game, he is notified that he "achieved" this goal. The user can accompany his list of goals in another screen on the game or in another place.
- *Customization:* The player can customize certain aspects of the game (normally related to graphical assets) at his will or from a certain pre-defined list of assets.
- *Storytelling/Environment Setting/Graphics/Music:* The game has artistic components that complement the overall game experience by themselves. These are usually very important on computer and console gaming, but a little less on mobile.
- *In-game Fictional Currency:* The player gets a fictional currency on the game after doing certain objectives or achieving certain milestones, which he can use to unlock or improve other aspects of the game (like the ones related to these other tactics).
- *In-game Purchases:* Successful on both mobile and console games (Digital Games), the player has the possibility to buy for real money something related to one of these others tactics (including fictional currency), which simplifies the acquisition of new content if the player is not willing to pass through the previously defined method by the designer.
- *Point-Based Ranking or Leaderboard:* Also present on Analog Games (e.g. Sports) and Digital Games generally, the fact that your progress and feedback is scored by points and those scores can be compared to those of other players induces competitiveness and further interest to the game.

2.3 Pervasive Storytelling

Storytelling as commonly known in today's games could be used in new innovative ways when applied in IoT Pervasive Games. A game with immersive and dynamic storytelling could make use of the *"Find the Thing"* base interaction, for example, and unfold its own story to the player following the data retrieved by him during interactions with placed tokens on an environment. It could also send a specific signal to the token, so that the story will be different when the next user arrives at said token (e.g. *"Change the Thing"*).

These are experiences that could be, in the near future we envision, very common in our daily lives and could be very well used for advertising, public events, social interactions, massive urban games, and more.

2.4 Game Mechanics and the Overall Player Experience

The design of a game in terms of its playability derives from various types of smaller simpler interactions. When these interactions are mixed with gamification tactics (notably environmental setting and storytelling), the game gives the player a sense of immersion and a complex experience that is usually greater than the sum of its smaller parts.

This principle is a key factor in general game design, but it is especially important in games that are dealing with new types of technologies, those of which usually lead to new base interactions such as the ones described previously as IoT/Pervasive mobile nodes and sensors interaction. When these factors are well worked, it means that the overall experience given by the game is a concise experience that will most likely be well absorbed by the player and, thus, lead to a successful game.

3 Validating Our Model – Qualitative Interviews

The goal of this evaluation is to inquire if the proposed method to abstract the interaction and gamification tactics for the design of Pervasive IoT Games into independent architectural elements is valid for those who will most likely use it, *game developers*. To validate this architectural proposition, we would like to assess if the proposed set of game elements is sufficient to abstract an independent game experience.

3.1 Methodology

Since our goal is to serve as guideline for game developers interested in pervasive mobile games and IoT, we aim with this interview to validate that, in a game developer view's, the model is sufficiently concise and robust to abstract the game elements of different categories of game experiences. On other level, we also search if the model is sufficient not only to abstract the game experience, but to fully describe it. Our goal is to have some confirmation from the developers that the model is at least sufficient for the abstraction of the experience, not directly aiming for the second "fully description" goal.

There are very few popular pervasive games on the market for us to define them as a specific game category for the interview. Because of that, we will use two other categories of games: *Analog Games* and *Digital Games* (both mobile and console).[4] These categories represent well the mixture of physical games in the real world and digital games on a virtual world in a way that fits what is accepted to be a Pervasive Game, since it breaks the known temporal and spatial boundaries of most games [2, 4, 6].

The interview was conducted with eight game developers, and it was proposed for the interviewee to analyze three different games. The games were *"Tag Game"* (Analog), *"Grand Theft Auto IV"* (Digital/Console Game) and *"Angry Birds"* (Digital/Mobile Game). The subject was asked to abstract the interaction and gamification tactics from the games according to the proposed elements of both categories in an annex of the interview.[5] After the analysis of each game, the interviewee was asked some questions about his acquiescence with the abstraction he/she just did, and also asked to comment further about it, making suggestions and critics for the model.

The interview was sent by email and Facebook for the interviewees, together with a small explanation about it, which comprehended: *That it was to prove or disprove a model to abstract game experiences; That criticism was highly acceptable; That in it they would analyze three games* - *and then proceeded listing them; That they had to check in Page 2 and 3 of the interview about the elements they would want to use to abstract the game experiences; That if they felt like it wasn't enough, they should explain why, and if necessary, propose other elements; and That when in doubt, just do what you think it's right.*

3.2 Result Analysis[6]

The eight interviewees were all Brazilians, male, average of 25 years old, 4.5 years of game developing experience and 20 years of experience as gamers. They all succeeded in choosing interactions and gamification tactics from the balloons in the annex to abstract each game, differing in their arguments on why they choose one or another balloon and on the abstraction itself.

Also, as it was expected, the acceptance of the model as "adequate" to abstract the player experience (Question 2–58 %) was higher than the acceptance of the model as being capable of "fully characterizing the player experience" (Question 3–30 %). By analyzing the structure of the negative feedback, we identified two main problems: a *structural problem* and a *content problem*. The structural problem is related to the structure of the model, which is either too abstract or too specialized on the types of interactions and gamification tactics. This is reflected on comments like this:

> *"The balloons were a bit confusing from a game development point, and some of them felt very specific to describe the games in question. This would prove to be a problem if the objective is to create descriptions that can apply to any game.!"*

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[4] More information can be found in the *Game Design and Interaction Analysis* at http://www.lac-rio.com/projects/pervasive-iot-games.

[5] The model of the interview, proposed interactive and gamification elements, full results and interview transcripts can be also accessed at http://www.lac-rio.com/projects/pervasive-iot-games.

[6] As was commented previously, the full and uncommented results of the interviews can be found at the LAC website, at the footnotes on the last page.

The other type of problem is a content problem, which happened when the interviewee could not find a specific interaction or tactic within the balloons:

"'Identify roles', or 'Identify others logical state'. Something related to each participant in a way to identify all the others as runners or chasers."

Which was most of the time because either the interviewee was confused and couldn't find a balloon that expressed what he wanted, or that balloon actually wasn't there, thus, expressing a "lack of content" problem. The content problem doesn't goes against the model, since it can be easily solved by simply increasing the variety of interactions and/or gamification tactics, which is not a structural problem with the model. By considering as negative acceptance only the structural problems, we see an increase in both acceptance rates for our "adequate" (67 %) and "fully characterizes" (63 %) game experiences.

It's also interesting that, from all three types of games, the one with the highest acceptance rate for the model is "Angry Birds", a mobile game with many strong gamification elements. The lowest was the "Tag Game", mainly because of the difficulty in visualizing gamification tactics for an Analog Game.

Although we discussed acceptance rates, our focus wasn't really on the statistics from the interviews, but for the actual feedback as how well the model can be used to abstract these experiences. In general, it was met with positive feedback, since all of the content problems are positive for the model validation. Like this answer for Question 2:

"No. They give great insight about the ambience of the game and player motivation, but lack one important aspect of gameplay that molds the whole player experience which are the puzzles that must be solved on each level. The scenarios present multiple obstacles that challenge the player both mentally (as he must discover the solution) and skillfully (as he must aim correctly to implement his strategy). Suggested balloons are: 'Puzzle' and 'Obstacle' (relation status with other elements)"

By suggesting the inclusion of balloons like "Puzzle" and "Obstacle", they are actually affirming that they understood the main concept, which is to mold the player experience with these interaction and gamification elements, which is even doable with the current suggested balloons, since the both experiences can be derived by smaller and simpler elements.

It is apparent for us that, after the interviews, the model is *sufficient* to abstract game experiences, dividing them into interaction elements and gamification elements, but not entirely adequate to fully describe all game's nuances and every possible iteration of player experience, since it is, as it was observed looking at the results, a *very different experience for each person*.

4 Case Study – Area Control Game with Mobile IoT

As part of a case study for our architectural analysis of Pervasive IoT games, we designed a game with enough features as to represent the proposed model. The game is still under development and its first version is due to the end of 2014.

The game is similar to the analog playground game known as *capture the flag*. It is a local multiplayer session game, meaning it is played by a certain number of people in a specific area and time, and it has finite duration. The players will carry *smart devices* supporting Bluetooth® Smart technology, and the flags will be *mobile objects with sensors* (such as the previously mentioned Texas Instruments Sensor Tag) capable of capturing contextual information from their environment and transmitting these sensed data through their Bluetooth® Smart interfaces.

4.1 Playability

Players are divided in two or three teams, each of which owns one or more flags. Flags are initially placed within a pre-determined area belonging to each team (Fig. 1).

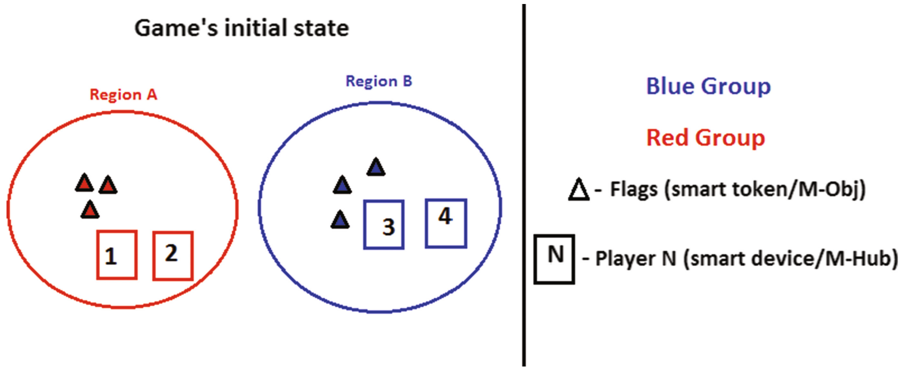

Fig. 1. A simple mockup of the game's initial state

The goal of each team is to take all the other team's flags and move them to their own region, but an opponent player can take flags only if they are unguarded. Players can guard their own flags by staying in the same region as theirs or by carrying them around the game area.

When players from different groups meet or a flag-taking attempt happens, the involved players engage in a battle. The battle winners can take a flag if the losers are carrying/guarding one, and the losers can't fight or steal flags for a period of time. The game ends when all the flags are owned by a single team.

Since the game's theme surrounds the idea of controlling an enemy's area and slowly advancing your position (it can be modified so that each group has several control areas, or maybe with control areas previously un-owned by both groups), its tentative codename is *Area Control Game with Mobile IoT*.

4.2 Tentative System Architecture

Players are viewed by the system as mobile devices and flags as mobile smart objects. The smart objects are not capable of direct connection with the server, so their location/state is only updated upon interaction with the players.

The server infers flag ownership considering the flag's last known location, last owner and last battle in which it was involved. The players are always sharing location information with the server and listening to broadcasts from the smart sensors (through Bluetooth). The server will notify a player if another player from a different group is nearby and their direction. If they are close enough, they can engage in battle, and only then the players will know if one of them is carrying a flag, being notified on their smart devices.

Player battles will occur through their smart devices following a *weighted rock-paper-scissors* method. Players will have experience points that will be counted as a weight on their attack choice, so a high level player can win a battle even choosing a weapon weak against the other players'. Players get more experience points by winning individual battles, capturing flags and winning games.

The system architecture on a lower level will follow the ContextNet Architecture for IoMT Collaborative Applications [14, 15]. This architecture will be further described in the Sect. 5 of this work.

4.3 IoT Pervasive Game Model Analysis

Being an IoT Pervasive game, the Area Control IoT Game should be abstractable through our Interaction/Gamification model:

Interaction Models. The game has direct interaction between players and things in a way that: Players have to "*Find Things"* and *"Change Things"*. Also, things interact with players in a way to broadcast their proximity, while player information is constantly updated to the server, which updates other players with the information, which interacts with other things. This means that, in a way, the interaction possibilities between things can mimic one of the *"Things color other things"* interaction.

Gamification Tactics. Since the players have experience points that influence on the game mechanics, we have the "*Improve certain user perks when the player is doing well"* aspect. Also, *"Achievements"*, "*Customization", "Storytelling", "Environment Setting"* and *"Graphics"* are all aspects that could act positively in the final gaming experience.

Re-construction of the Game Experience Experiment. The idea is that if we change an interaction and/or a gamification tactic to some other, the game experience will still be concise, but the final game will be entirely different.

For example, if we remove the *"Change the Thing"* interaction and add *"Guess where things will be"*, we can come up with a game in which some sensors are fixed and visible to the player (broadcasting proximity) and others are movable but untraceable. The players have to find (*"Find the Thing"*) the fixed sensor to receive a clue about the whereabouts of the movable thing. After that, the player will follow the clue so than it can reach the movable thing close enough, and by doing that he receives a point.

A ranking (*"Point-based leaderboard"*) of the players with most findings can be updated daily do that the players can compete with each other (removing the *"Improve user perks"* in this case).

With this exercise, we can assess that by changing a few elements of the base interactions between game elements and the gamification tactics employed in the game, we can drastically change the final game experience for the player.

5 The ContextNet Architecture

Project ContextNet is primarily focused on developing middleware services and APIs aimed at facilitating the development of large-scale context-aware pervasive and mobile applications [10]. It is in constant evolution, but it has already been used for the development of some quite complex distributed mobile applications.[7] The code is freely available for download,[8] but not open source. This middleware and its recent extension for IoT will be used as the basis for developing multiplayer Pervasive IoT Games.

5.1 The Communication Middleware

ContextNet defines a high-performance mobile communication middleware, called *Scalable Data Distribution Layer (SDDL)* [11]. This middleware connects Stationary Nodes of a core network (*a.k.a*., the *SDDL Core*) with all Mobile Nodes. While the former are desktops or servers executing in a cluster, or cloud, over the OMG DDS [12] middleware, the latter are mobile end user devices (i.e. smartphones and tablets).

The SDDL communication protocol for inbound-outbound communication between the SDDL Core and the mobile nodes is the Mobile Reliable UDP (MR-UDP) [13]. In a nutshell, MR-UDP is Reliable-UDP with mechanisms for tolerating intermittent connectivity, dynamic IP address changes of the Mobile nodes and reaching these nodes behind firewalls/NATs. It is used by the mobile nodes to connect with a special type of SDDL Core node called *Gateway*, of which any number can be deployed in the SDDL Core. Each Gateway maintains one independent MR-UDP connection with each mobile node, and is responsible for translating application-messages from MR-UDP to the intra-SDDL core protocol, and, in the opposite direction, converting core messages to MR-UDP messages and delivering them reliably to the corresponding mobile nodes.

The SDDL Core has several other specialized nodes (see Fig. 2): the *PoA-Manager*, which holds the addresses list of all currently active Gateways and eventually requests mobile nodes to switch Gateways; *GroupDefiners* evaluate the group-memberships of all mobile nodes (based on some attribute of their inbound application messages) and

[7] More information at http://www.lac-rio.com/projects.

[8] Accessible at http://www.lac-rio.com/software.

manage the reliable delivery of group-cast messages to the mobiles, and the *Controller*, which provides a Map-based user interface to visualize and interact with any mobile node of the system.

Finally, there is the *ClientLib (CNCLib)*, a Java library which establishes and manages a MR-UDP connection of a mobile node client (in Java, Android or Lua), and the Gateways. It hides most MR-UDP details end error handling from the application layer, and supports application-transparent handover of the mobile node between SDDL Gateways.

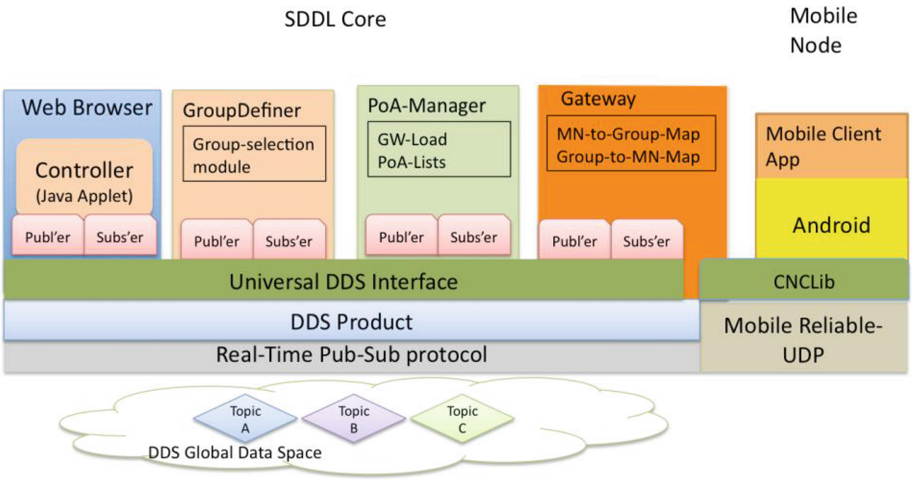

Fig. 2. Nodes and protocols used in SDDL, as seen in [11].

The SDDL has been extensively tested in lab experiments, mainly because we wanted to test the system with thousands of mobile nodes, and doing such large-scale tests in with real devices the field is not feasible. In our performance tests, we observed that the Gateways support up to 5000 simultaneous MR-UDP connections each and a total throughput of 5000 messages/s inbound. However, we have also tested the SDDL middleware over 2G/3G wireless Internet connections (while the testers roamed through the city), and obtained good results with respect to latency and message loss. More details of our performance tests can be found in Sect. 4 of [11].

5.2 SDDL as a Middleware for IoT Games

In the last couple of months, the ContextNet project embraced support for applications in the *Internet of Mobile Things* (IoMT). Therefore, the SDDL middleware was extended with the concept of a *Mobile Hub (M-Hub)* [14, 15]. In IoMT, a "smart thing or object" can/will be mobile, and is therefore called *Mobile Object (M-OBJ).* M-OBJs have short-range wireless communication allowing them to interact with nearby Mobile Hubs. These M-Hubs are portable devices, such as smartphones, which: (a) have

MR-UDP connectivity with a Gateway of the SDDL Core in the a cloud; (b) have means of obtaining their current geographic position and (c) have a short-range wireless communication interface, allowing them to discover, connect and interact with close M-OBJs.

We plan to use this SDDL middleware extension for IoMT as the basis for our Pervasive IoT Game, the *Area Control Game*. Essentially, it will consists of mobile clients and one or more *Game Processing Nodes (GPN*), to be deployed in the SDDL Core. The *GPN* will be responsible for the long-range communication as it processes the information passed by the gateways, primarily received from the M-Hubs (Fig. 3).

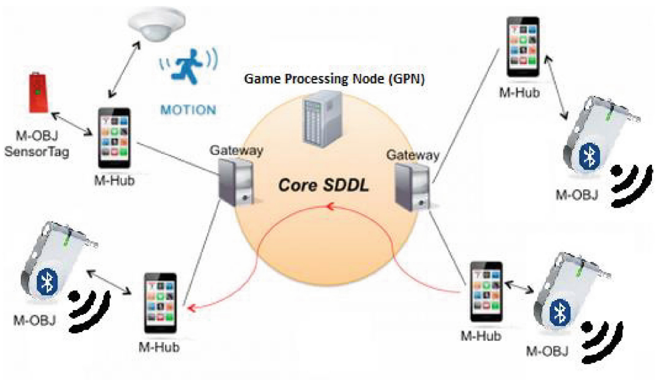

Fig. 3. GPNs computes contextual information from the M-Hubs and M-OBJs, like location.

Besides our Area Control Game case study, we idealized a few examples of perfectly implementable IoT Pervasive games using the ContextNet Middleware technology for mobile nodes communication. Below is the idealized architecture for these examples summarized:

- **Sensor and Token Structures (Mobile Object or M-ObJ)**
  - They have a UUID[9] and some set of attributes.
  - They can broadcast and unicast small packets of information to M-Hubs and to each other (but only through M-Hubs).
  - They will most likely use the Bluetooth® LE Technology, but can also use other types of communication technology, since the GPN is capable of abstracting the data it receives and pass it forth.
  - Most of them will also have some on-board sensors that reveal information of the object's current state and environment (e.g. temperature)
  - They can have memory, so they can store the information sent by the M-Hubs.

[9] A universally unique identifier is an identifier standard used in software construction, standardized by the Open Software Foundation as part of the Distributed Computing Environment: http://en.wikipedia.org/wiki/Universally_unique_identifier.

- **Mobile Hubs (M-Hub)**
  - The smart devices carried by the users. They must be able to "synch" with more than one M-Obj at the same time.
  - They must be capable of mixing information obtained from the Internet with information obtained from nearby M-Objs.
  - They should preferable have access to GPS, as most of the interesting applications are Location Based, but thats not mandatory.
  - They will communicate with other M-Hubs and possibly with a cloud service through the SDDL Middleware.
  - Have much greater storage, processing and battery capacity than M-Objs.
  - Acts as the long-haul communication intermediary for M-OBJs in its proximity, as well as a point of reference.

Also, we just finished a first prototype of M-Hub for Android. This prototype runs on our Moto E smart phone, which has Bluetooth® Smart and already detects and connects to nearby Bluetooth devices playing the role of a M-OBJ. The M-Hub already attaches its current GPS coordinate to the M-OBJ's sensor data, and sends a JSON message, via MR-UDP whenever it connects or disconnects from the M-OBJ.

We also observed that the discovery and connection times of a M-OBJ to a M-Hub takes at most 9 s when the Bluetooth Smart connects for the first time, but only 300 ms on all the following connections.

6 Conclusion

We believe that all technology needed to implement these ideas are already at hand. This work's main goal is to organize design patterns, strategies and important features that should exist in future IoT Pervasive games, so that future developers can properly use these ideas.

Another objective we have is to show through our case studies how IoT Gaming can have great social and cultural impact as they can be used to encourage participatory sensing for urban development, collective action, to report problems (like crackling sidewalks on urban areas), and urban environment. These can be achieved mainly through a clever use of both base interactions and gamification tactics.

Thus, by showing a few examples of case studies of such games using our ContextNet Architecture for IoMT applications, and by analyzing our feedback from the model validation interview, we are able to confirm that these strategies are capable of achieving their main goal: to build new engaging pervasive game experiences.

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