A Text-to-Picture m-Learning System in a Private Wireless Mesh Network

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Abstract— **Mobile devices can assist students in improving their learning capabilities and comprehension skills. A dedicated network connection is required to enable device communication and information exchange. In this study we propose a Text-to-Picture (TTP) mobile educational system that displays illustrative pictures to characterize the content of Arabic stories and synchronize information automatically among the connected devices in a private wireless mesh network. The device of the instructor can connect to the Internet to download further information. It shares Bluetooth connection with at least one student. Therefore, students can connect among each other to synchronize information that will be automatically displayed on their devices. The aim of our proposed study is to provide a complete educational system that can communicate in a private wireless mesh network without having a reliant infrastructure.**

Keywords— Mobile Learning; Text Processing; Formal Concept Analysis; Education; Wireless Mesh Network.

I. INTRODUCTION

Nowadays network based collaborative work plays a vital role in the success of most corporations or companies. As most people living in metropolitan cities own handheld private mobile smart phones, they become the main means of communication between staff. People working on common projects may benefit greatly from network based collaboration that allows for shared workspace, shared files, information, and timeline up keeping. Currently there are various systems available that provide options for collaborative work in a corporate environment. However, not many reliable options exist to support a collaborative classroom environment. Other studies have proposed collaborative learning or communication platforms [1,2,3,4,5] but do not provide functionalities such as illustrative pictures, attendance conduction, quizzing, and other interactive classroom events needed.

Mobile devices may be exploited in classrooms as most students and teachers already own a mobile device. A mobile network based collaborative classroom environment would be feasibly set up with low overhead costs. In this study we propose a novel system framework that would allot for utilization of mobile phones to obtain a collaborative classroom environment where students can learn more about the texts they are reading, by an automated text-to-picture application that functions dynamically without having a reliant infrastructure. The instructor can prepare the reading materials at home and select best illustrations to use them for his/her students. If the mobile device of the instructor contains all the content, it will not require Internet access. Hence, all students in the classroom can get data from the device of the instructor in the private network.

The paper is organized as follows: section II discusses some previous works. Section III presents the learning system with its features. Section IV gives details on the system implementation. And finally section V concludes the paper.

II. BACKGROUNDS

There are several applications and software that support collaborative learning or communication. Lotus Sametime Connect [1] allocates options for collaborative multiway chat, web conferencing, location awareness, etc. Microsoft SharePoint [2] allows for online collaborative development for documents and websites. BSCW [3] also allows for online sharing of workspaces between distant people. It provides mobile device interfaces and communication is done via mobile networks. It is not however, customized for classroom learning environment. Groove [4] is another application that allows users to utilize networking for collaborative working. Groove stores all data on the users' local machine and provides flexibility to all users for management of content. Accessibility is controlled and allocated accordingly. A set of collaborative services such as thread messages, project workspace, discussions, document sharing are also provided. Similar to BSCW, Groove also has a mobile interface for communication, but it is also not customized for classroom learning environments.

PhpGroupware [5] is an open source application that also allows for collaborative work. It provides features such as email, graphics and attachment sharing, calendar, file manager, address book and other features. Groupware [6] provides more features such as allowing internal news broadcasting, share notes as instructions, an outboard function to keep track of participants, and an album containing all information about users.

Google Wave [7] provides many functions such as drag and drop sharing, autocorrect features, embedding thread or work into blog or website options and can translate work dynamically.

The work in [8] proposes software architecture for next generation collaborative software support. The proposed architecture involves mobility and implementation of Peer-to-Peer (P2P) technology for dynamic network based collaboration of mobile nodes.

Wanyonyi [9] developed an m-learning application that uses task-timer model to perform synchronization every period with the server to provide near-real time streaming of presenting slides between desktop users and mobiles ones. RikWik [10], wiki engine, has been proposed by Queensland University of Technology (QUT) researchers. It is developed using Microsoft ASP.net. It aims to provide secure, flexible, and extensible environment for collaboration work. Huang et al. [11] used RikWik engine to provide mobile support including the basic support of cooperative work. Georgiev et al. [12] proposed a solution for collaborative network on mobiles. It enables mobile devices to establish network communication on the fly, and reduces deployment expenses by using the available wireless technologies.

Saad et al. [13] proposed an intelligent collaborative system that can enable small range of mobile devices to communicate using WLAN, and uses the Bluetooth in case of power outage. The mobile device attempts to connect the server to access available server services. The student can make quizzes, access the lecture material, mark his attendance, and send queries to the instructor. The architecture of the proposed system is central where client can connect the server. Saleem [14] proposed a Bluetooth Assessment System (BAS) to use Bluetooth as an alternative to transfer questions and answers between the instructor and students. The proposed system is divided to two parts: 1) instructor part: it enables the instructor to set the question of exams, check answers of students, and monitor exam events, and 2) student part: it enables students to submit the answers of exams.

As many systems have been developed in the domain of network based collaboration, several of them have used mobile technology while others have not. However, very few of the collaborative technologies proposed adopt a classroom environment based on mesh communication to connect to its neighboring device in an ad hoc fashion to get required data. In this study we propose a collaborative learning system that can be implemented using handheld mobile devices, customized to the classroom environment, using a private Bluetooth wireless mesh network.

III. THE PROPOSED SYSTEM

Our proposed system can generate multimedia tutorials and synchronize the content in a Bluetooth wireless mesh network. It can be used in classrooms without having a reliant infrastructure. The system broadcasts messages to enable users to follow the instructions of the teacher on their mobile devices.

In order to create multimedia tutorials, we have collected so far thirty educational stories for children and manually added their words to a corpus. The main concepts (entities) of Arabic stories are illustrated by pictures. Thus the students can conceive graphical depiction of entities linked to their properties (e.g., light yellow color, lives in forest, etc.) and their behaviors (e.g., drinks milk, can fly, etc.). For instance, for the sentence ‘the white cat is drinking milk’, the student can see the pictures of the cat as it is a named-entity.

The device of the instructor is the primary device that shares the main connection with at least one student. It can connect to the Internet to get further information. For instance, it can send a request to an online search engine (i.e., Google) to get additional multimedia elements not available on a shared repository. The dynamic multimedia content in a private scalable mesh network would prove its efficiency in its ability to reduce the traffic on the global network.

The system is composed of several components which are the following: 1) Arabic text parsing: provides natural text processing for the text to extract entities, word-to-word relationships, multimedia elements that depict that content of the text, and semantic explanations for domain words (e.g., animal-related words, food-related words, etc.) 2) Primary communication provider (PCP): it is the main component that communicates with the Arabic text parsing server. It is the primary provider of educational content and multimedia items. And 3) Client communication provider (CCP): it communicates with the PCP to get new or missing information. A CCP can connect a set of client communication providers (CCPs), or to the PCP. One CCP at least must connect to PCP in a set of CCPs, otherwise the connection will be automatically terminated according to the primary heartbeat interval and clients will attempt to communicate to other providers. Figure 1 shows established connections between PCP and different CCPs.

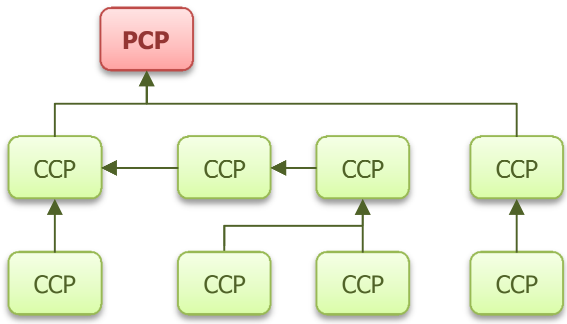


Fig. 1. PCP and CCP connections.

A. Applied Methodology

We have used the IEEE 1074-2006 standard criterion to develop our system. It is a standard for evolving software project life cycle procedure [15]. We have defined modules, classes, and designed the user interface. We have designed an ontology to add substantial information about entities in the animal domain. We have added detailed information about each entity and asked different questions during the development of the ontology. For instance, *where do the lions live*? *What do they eat*? *What are their behaviours*? *Are they carnivorous or herbivorous?* We have added most general classes and created their inherited ones (e.g., the concept Carnivorous is a sub class of the Animal concept).

B. Text processing and feature extraction

The processing of the text passes through different phases: 1) Segmentation: the text will be split into paragraphs and sentences. Each paragraph is split into sentences of several words. 2) Entity-relationships: it is based on applying formal concept analysis to extract contextual relations (triplet) through composition of entity-property matrices. The entity-sentence matrix is constructed according to the occurrence of the entities (e.g., lion, tiger, etc.) and their corresponding sentences as shown in Figure 2 (a). The property-sentence matrix is constructed according to the occurrence of properties' values (e.g., white → color, run → behavior, etc.) and their corresponding sentences as shown in Figure 2 (b). The composition of the two matrices will provide the contextual-relation of all entities and their properties as shown in Figure 2 (c). For instance, the sentence 'the lion is running, its color is brown' will provide two contextual relations: {lion: [behavior: run]} and {lion: [color: brown]}. Hence the two relations can be merged together with the same entity to become: {lion: [behavior: run; color: brown]}.

	S1	S2
E1	1	0
E2	0	1

(a)

	S1	S2
P1	1	0
P2	0	1
P3	1	0

(b)

	S1	S2
E1	1	0
E2	0	1

×

	P1	P2	P3
S1	1	0	1
S2	0	1	0

=

	P1	P2	P3
E1	1	0	1
E2	0	1	0

(c)

Fig. 2. Entity-Property matrix

If multiple entities appeared in the same sentence, the distance between words is computed to link entities with their nearest property values as shown in Figure 3.

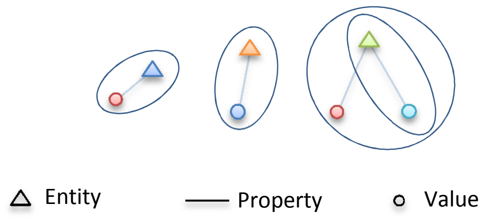


Fig. 3. Linkage between multiple entities

3) Semantic Relation Extraction (SER): It is one of the intelligent missions that are achieved by our system. It can determine entity acquaintance and feasible relationships with other entities based on semantic rules. For instance, for the definition, 'the tiger is a carnivorous and can eat gazelle', if we define that a lion is carnivorous, we can infer that it can also eat gazelle. The SER is used also for knowledge extraction (i.e., entity, property, behaviour, etc.) that is needed during the phase of entity-relationships. 4) Semantic Queries: they will be generated dynamically according to the determined contextual-relations. The query can vary according to the place it will be used in (e.g., extractions from the ontology, retrieval from google search engine, etc.). The obtained results are mapped and stored in mapping-tables (i.e., hash tables) which allow quick retrieval of information. Eventually, results contain all semantic information about entities, associated details, and related illustrations. Figure 4 shows the different text processing phases to generate the illustrations.

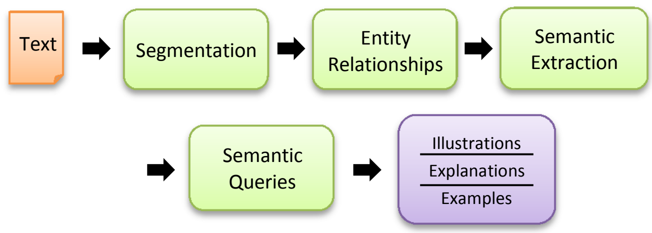


Fig. 4. Text processing phases.

C. Ontology Architecture

The ontology is created using Protégé [16], an open source tool for editing ontologies and knowledge procurement system. It supports the development of ontologies and reserves an application platform with knowledge based systems. Declaring an instance of a specific class type requires: 1) selection of the class; 2) creation of an instance, and 3) filling values of the instance. Figure 5 shows a section of the created educational ontology.

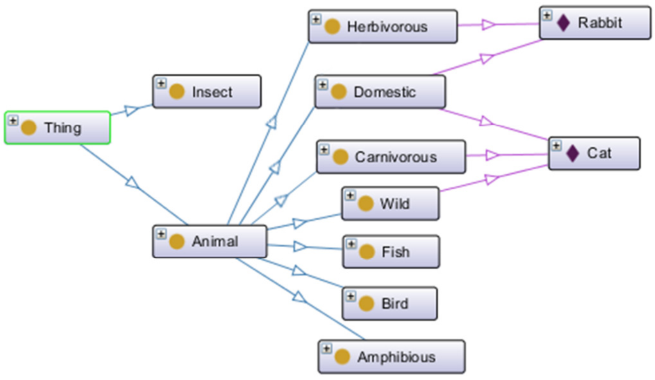


Fig. 5. A section of the created ontology.

D. Distribution of Messages (broadcasting information)

In general, the PCP is the main distributor of information to its connected CCPs. Once a CCP receives a *broadcast* message, it will send it to all its connected CCPs. The distribution of messages is sent in a hierarchical path as shown in Figure 6. The GUID of the message, the submission time of the PCP, and the received time from the CCP are logged together to examine the performance of distribution.

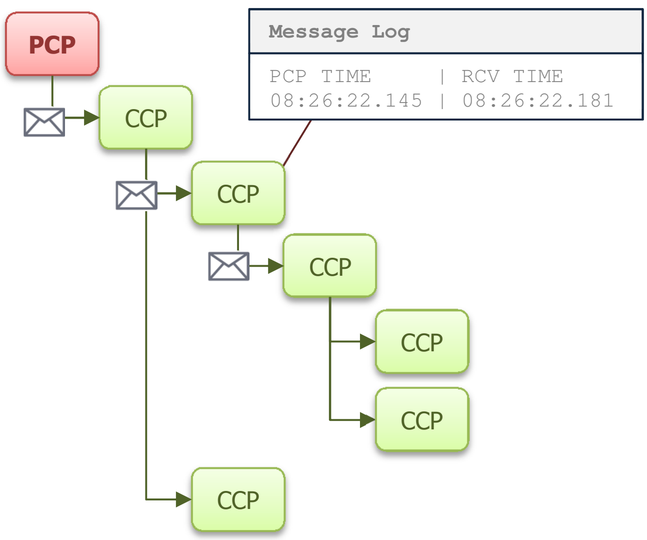


Fig. 6. Distribution of a message on CCPs

E. Message Structure

The message is a serialized in JSON [17] format. It is composed of three sections: 1) *message ID*: is a globally unique identifier (GUID) to identify the message; 2) *header*: used to identify the type of the message (e.g., heartbeat, broadcast, etc.); 3) *content*: contains the content that will be displayed on the client device and the picture ID; the picture message has the same structure of the broadcast message; it contains the picture ID and the buffer of the picture; it is identified by the *pic* value in the header.

IV. System and Mobile Application Implementation

A. Proposed Modules

Figure 7 shows the different modules that are complementary to fulfil the processing and illustration generation operation in the proposed system. The *Presentation* module is responsible of updating user content according to the received message. The *Communication* module supplies connection services. The *Cache Manager* module is used to read and save pictures that will be stored on the local device. The *Settings* module is used to manage the configuration of the user device (e.g., primary device -- *requires administrator password*, font size, color, etc.).

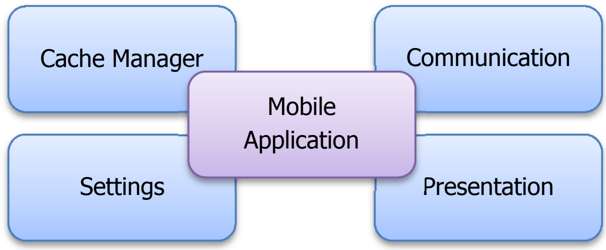


Fig. 7. The system modules.

B. System Architecture

The system architecture is composed from three parts: an Arabic natural processing server, primary mobile communication provider, and client one as shown in Figure 8. The main benefits of this architecture are: 1) to separate the logic of processing information from the presentation; 2) to provide a secure reliable connection; 3) to access the internet only when it is required; and 4) to adapt clients' communication in a private wireless mesh network without having a reliant infrastructure.

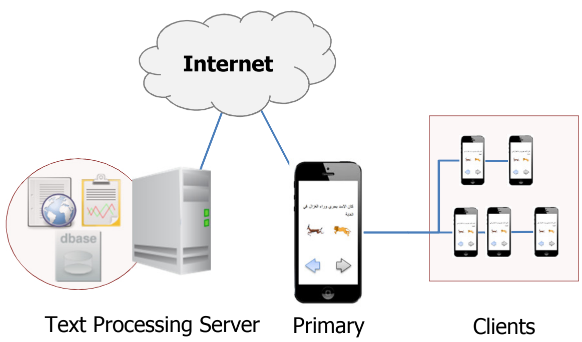


Fig. 8. The proposed architecture.

The Client mobile application is a hybrid application based on HTML5 technology that can work on smart devices (e.g., iPhone or Android). The client application establishes a Bluetooth full-duplex TCP connection with the neighbour device or with the primary one to obtain reliable information and latest updates. Each device can recognize connected devices and distribute messages among them. Eventually, Figure 9 depicts a sample log of a client device. The GUID contains the initial time of the message sent by the parent device or the primary device, and on the right side the received time on the client side.

```
GUID                                 TYPE  RCV
1c29dc6b-afc8-ff1f-f820-39d36a4008c1 B     63580183464129
077e3943-af4b-ff1f-f820-39d36a40d8d9 B     63580183517401
a42fb313-af79-ff1f-f820-39d36a4150fe H     63580183548158
55a01670-af8e-ff1f-f820-39d36a41ae2b B     63580183572011
24fd7b3d-afd9-ff1f-f820-39d36a421250 B     63580183597648
```

Fig. 9. A part of client log.

C. The GUID structure

The globally unique identifier (GUID) is composed into different sections as shown in Figure 10. The first two bytes identifies the type of the message. The *tt bytes* store the submission time of the message in nanoseconds. The *pp bytes* store the message type index. The *ii bytes* store the working index at a specific time. The working index is required to provide different GUID for messages sent at the same time interval. The *aa bytes* store the authorization number generated by the server. The authorization number stores the registered primary user who will use the PCP service. And the remaining bytes denoted by *xx,* contain randomly generated numbers.

```
xxxxxxxx-ppxx-xiii-aaaa-tttttttttttt

x: random numbers
p: message type
i: indexing field
a: authorization number
t: timestamp
```

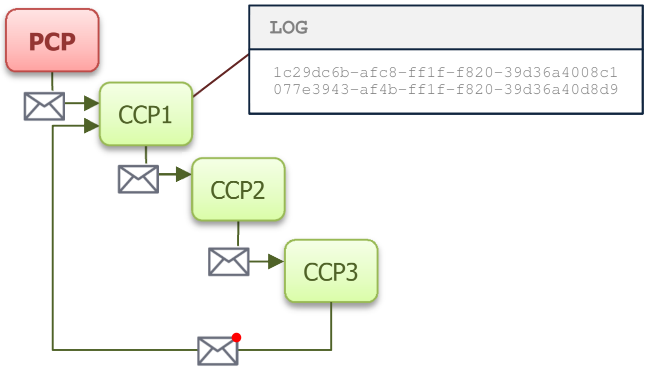
Fig. 10. GUID structure.

D. Messages Types

There are four different types of messages: 1) *heartbeat*: a periodic message sent initially from the PCP device to its connected CCP devices. Therefore, all CCP devices will share the heartbeat message with all their connected sub-CCPs, 2) *broadcast*: the message that contains information that should be distributed among all client devices, 3) *getpic*: a request message sent to the parent communication provider to get new picture or missing picture on the device, 4) *pic*: the message that contains the buffer of the message, and 5) *getlast*: is a request message sent to the parent provider to get the last message. It is often used when the client device joins the private network late or if it lost the connection.

E. Mesh Communication

The communication in the mesh network is based on broadcasting messages between connected devices. Broadcasted messages will be sent once, if the client identified that it received a message that was already previously received, it will be eliminated by comparing the key of the message. This happens in circular connections or if the client is connected to two providers as shown in Figure 11.




```
CCP1 will determine that the message of CCP3 was
already received. The message will be not sent again
```

Fig. 11. Elimination of messages.

F. System Operation

Whenever the server is launched, it loads its components and plugins as shown in Figure 12. It loads the text parser component, the defined ontology, and eventually it opens a TCP connection to wait for users' requests. Hence, intensive processing phases are done on the server side to decrease power consumption on the client side (i.e., mobile device). After starting the primary mobile application (PCP), it attempts to connect the server to validate if the provided authentication is veracious and sets up the connection accordingly. Hence, the PCP device can perform elementary processing phases if it cannot reach the server (e.g., no access to multimedia repository, no access to corpus, etc.).

```
Launching NLP Server...

Loading Ontology Reader components...
Ontology in "Resources/Ontologies/ontology.ar.v2.1.2.owl"
Reading ontology "Resources/Ontologies/ontology.ar.v2.1.2.owl"
Ontology loaded successfully
Loading Stanford Parser components...
Stanford parser loaded successfully


Listening at:
tcp://10.10.20.45:12101
tcp://HARMAN:12101
stomp://10.10.20.45:61612
ws://10.10.20.45:61615


NLP Server is ready to receive connections
-------------------------------------------------------------------------
Enter your command:
```

Fig. 12. The NLP server startup.

Upon successful connection with the server, the server logs all events to enable the administrator to perform analysis, get necessary information, and trace any raised failure as shown in Figure 13. In addition, the administrator can configure the server to promptly report by email: 1) critical failures;

2) processing time exceeds the limit; or 3) if the memory reaches specific limit.

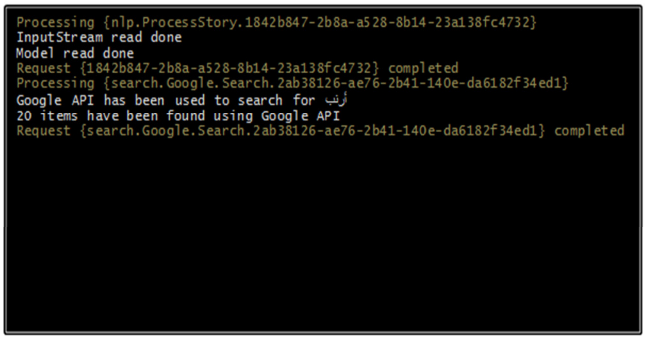


Fig. 13. Processing the user mobile request.

Whenever the primary application is launched, it creates a reliable TCP socket connection via Bluetooth and waits for users' requests. The primary application controls the synchronization messages that will be distributed in the private wireless mesh network. Hence, all processing phases are done on the primary device and on the server. Once the client mobile application is started, it assays to connect any available device. If the device did not receive a heartbeat within the configured interval, therefore, it attempts to connect to another device. Figure 14 shows the log on the PCP device.

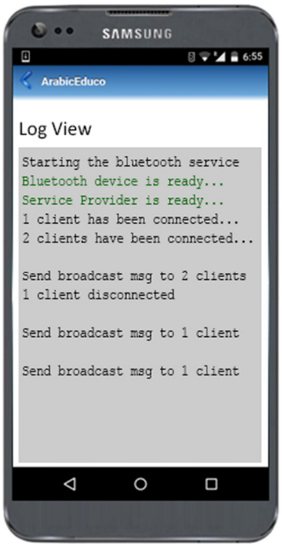


Fig. 14. Mobile application log.

Upon an effective connection trial, the user will wait for *broadcast* messages from the parent device to update the content on the user device and broadcast messages to connected devices. When the instructor navigates in the content of a story, a broadcast message is serialized in a JSON format composed of; 1) the header, containing a *broadcast* value, 2) the content that will be displayed, and 3) the picture ID. The receiver of the message will check if the picture is already stored on the device. If the picture is not stored, a request will be sent to the message sender to get the required picture. During the phase of getting new pictures by a device, requests of connected devices stay on hold until pictures have been received on the device itself. Figure 15 shows PCP device-to-server sequence diagram to illustrate the various phases of communications.

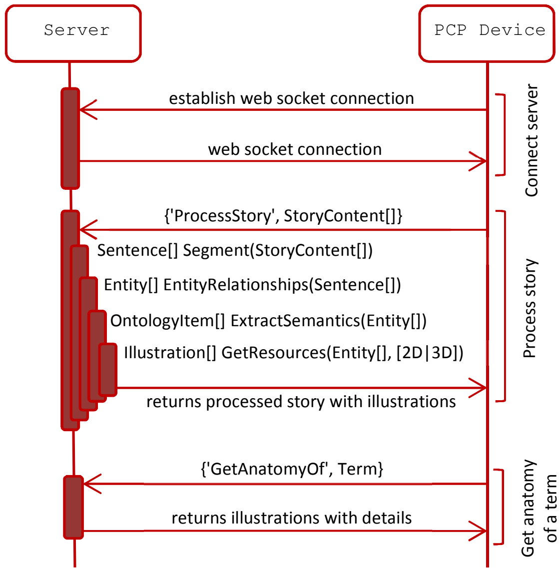


Fig. 15. PCP-Server sequence diagram.

Figure 16 demonstrates different phases between the PCP device and two connected CCP devices.

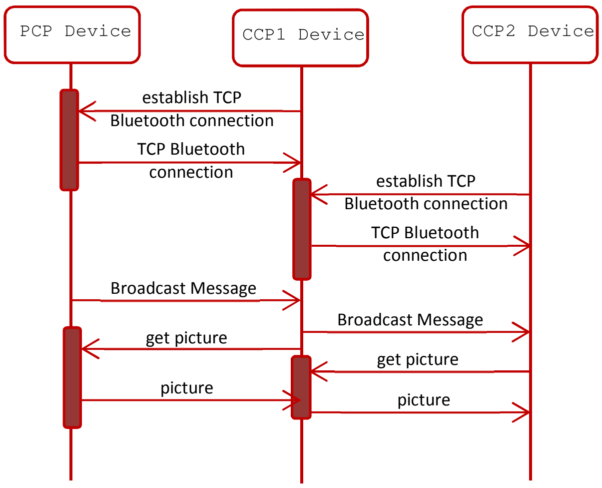


Fig. 16. PCP and CCP devices sequence diagram.

While the application is running, it stores in a log file: when the application started, when it is closed, the GUID of all received messages, and the receipt time of each. The log file is used to validate the receipt of messages and to compare the delay used before receiving the message.

When the client finishes processing the broadcast message, it loads the content, retrieves the required pictures, and displays them. Finally, Figure 17 shows the different screens that will be displayed for students while the instructor is providing the lesson.

Fig. 17. Launching the mobile application on Android devices.

V. Conclusion

This study presents a complete mobile-based system that automatically generates illustrations for Arabic stories through natural text processing and synchronizes the content of connected devices in a dynamically constructed Bluetooth wireless mesh network. The synchronization is based on broadcasting messages between all devices. The device uses a temporary UID table to validate if the message was already received. A broadcast message is sent from the primary device to inform connected devices that they are connected to the server. If a device does not receive the broadcast message from any device, it will attempt to automatically to connect other devices. Any device can connect to any neighbour device at any time and get latest synchronization messages. The proposed system can be used in class rooms and can operate without having a reliant infrastructure.

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