IoT Smart Device for e-Learning Content Sharing on Hybrid Cloud Environment

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***Abstract*—Centralized e-Learning technology has dominated the learning ecosystem that brings a lot of potential usage on media rich learning materials. However, the centralized architecture has their own constraint to support large number of users for accessing large size of learning contents. On the other hand, Content Delivery Network (CDN) solution which relies on distributed architecture provides an alternative solution to eliminate bottleneck access. Although CDN is an effective solution, the implementation of technology is expensive and has less impact for student who lives in limited or non-existence internet access in geographical area. In this paper, we introduce an IoT smart device to provide e-Learning access for content sharing on hybrid cloud environment with distributed peer-to-peer communication solution for data synchronization and updates. The IoT smart device acts as an intermediate device between user and cloud services, and provides content sharing solution without fully depending on the cloud server.**

Keywords—IoT, hybrid cloud, learning platform, internet bandwidth

I. INTRODUCTION

E-Learning has a great impact in our daily life and transforming the way how people learn. The technology has evolved from standalone system, to web based, mobile and utilizing cloud service as a learning platform. The revolution of delivering content in e-Learning has improved over the time due to increase number of users and learning materials, from single hosting server towards content delivery network (CDN) which involve numerous distributed servers across the network to avoid access bottleneck. CDN on cloud platform service is a technology to improve the efficiency of content delivery by decentralizing the streaming servers [1-3]. It offers a better access of learning materials where all the materials are replicated in multiple servers across the large-scale IP-based networks to guarantee the reliability of content access to avoid bottleneck problem. Even though CDN is a possible solution, the implementation of the technology is not the most cost effective solution.

In this research, we introduced an IoT smart device for e-Learning content sharing, which can be deployed in multiple locations, able to communicate with other IoT smart devices for sharing learning materials and hybrid with a public cloud platform for data synchronization and updates. The IoT smart device provides local learning content access and able to retrieve, share and distribute content amongst the devices. The solution will benefit the users by reducing the e-Learning content deployment costs, eliminating bandwidth related problems, improving access times, and increasing the global availability of the learning content to reduce full dependency on public cloud service.

The remainder of the paper is organized as follows: Section 2 discusses related works on overlay gaps of IoT smart devices and the assignment problem along with their current use. Section 3 presents the approach to solved problem in this case. The system architecture will be described in Section 4. The paper ends with a conclusion and future works.

II. RELATED WORKS

Performed work by [1], CDNs aim to distribute learning content on various sites within independent networks to avoid congestion and provides uninterruptable access. The IoT smart device aims to optimize the system availability with limited resources [4]. It is worth noting that those learning content distribution techniques can be based on a P2P structure as well as on a cloud structure which identified as a hybrid solution. Performed work by [5], they investigated content distribution techniques in both CDNs and P2P networks that are utilized to decrease the traffic load on backbone networks or to optimize content users' experience by shorter end-to-end paths and delays. The motivations of existing content distribution techniques based on CDNs or P2P networks range from improving final users' experience to compressing access cost such as link traffic.

Some issues are described in [6] and [7] such as: (i) the types of P2P networks for video streaming applications, (ii) the heterogeneity of peers and (iii) the inherent dynamics in P2P networks. Previously, proposal by [8] describes some problem with P2P such as: streaming cost, maximum delay and throughput, also work by [9] and [10] showed a problem in content replication.

978-1-5386-0549-3/17/$31.00 ©2017 IEEE

Meanwhile, proposal work by [11], [12] and [13] described the IoT devices in cloud computing and communication technique. The contents are distributed within multiple server-nodes with cost-effective and reliable IoT devices connectivity in heterogeneous network. Furthermore, presented by [14], studied combine between e-Learning and cloud computing environment is evidently a valuable area to be explored.

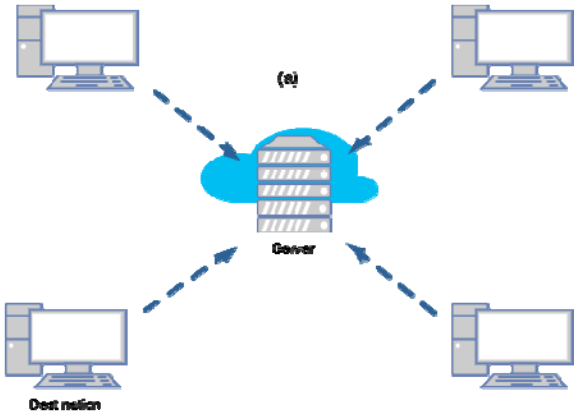
III. OUR APPROACH

To build the IoT smart device for e-Learning content sharing, which are capable to provide media rich learning content and material under limited resource condition, several hybrid techniques are required. Firstly, public cloud server is implemented to distribute the learning content to smart device nodes. Next, Peer to Peer Content Delivery technique is used to share the resources between the distributed device nodes. Finally, the smart device provides client accessibility of the learning content. The solution provides a continuous access, easy mobility and cost efficiency. The following sub-sections give an overview description of each technique that is implemented by the proposed IoT smart devices, (i) Content Delivery Network (CDN), (ii) Peer to Peer Content Delivery (P2P) and (iii) IoT Smart Devices.

A. Content Delivery Network (CDN)

CDN architecture consists of distributed servers (network) and management system which able to load balance the content access based on the geographic area. CDN are efficient to deliver the large size of digital objects such as multimedia content and multimedia streams such as video streams over IP networks to large amount of users. Typically, the management system of CDN manages the content distribution, request routing, reporting, metadata and other aspects that make the system work.

Implemented CDNs are based on web services of distribution nodes on cloud to manage content distribution decisions. The control function manages the distribution nodes and user request. It will identify the origin of the user request and decides from which CDN server to deliver the content.



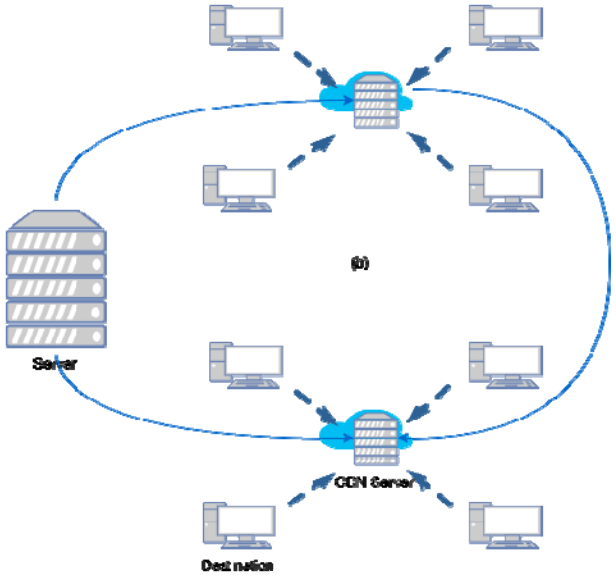


Fig. 1. Content Distribution without (a) and with (b) CDN.

In a content distribution without using CDNs, all the digital contents are stored in a single server and it has to distribute the content to every requested node. This will cause content delivery bottleneck when it tries to handle large number of requests from many nodes. However, by implementing multiple servers which sharing the same digital content, it can effectively distribute the burden of huge traffic volume to each server and allow a smooth access. Figure 1, illustrated the situations.

B. Peer to Peer Content Delivery (P2P)

P2P is a sharing protocol for sharing digital content and media files by end-to-end client nodes direct exchange. Delivering content between nodes empowering the individual storage, computing power and bandwidth and is considered as sustainable implementation. P2P networks provide solution on the high dependency on a client-server model where each machine acts as both a client and a server in the network as shown in Figure 2.

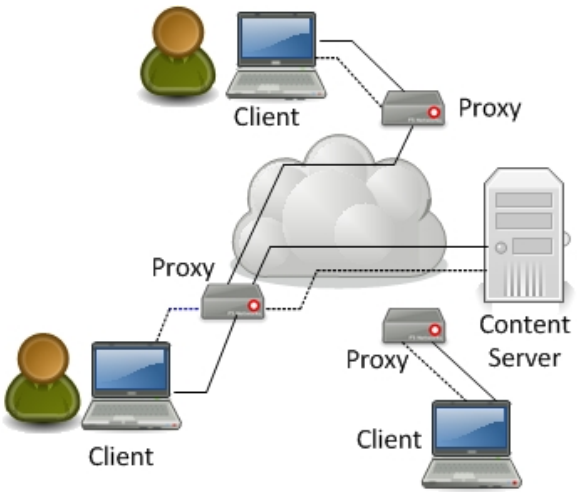


Fig. 2. Peer to Peer Content Delivery Architecture.

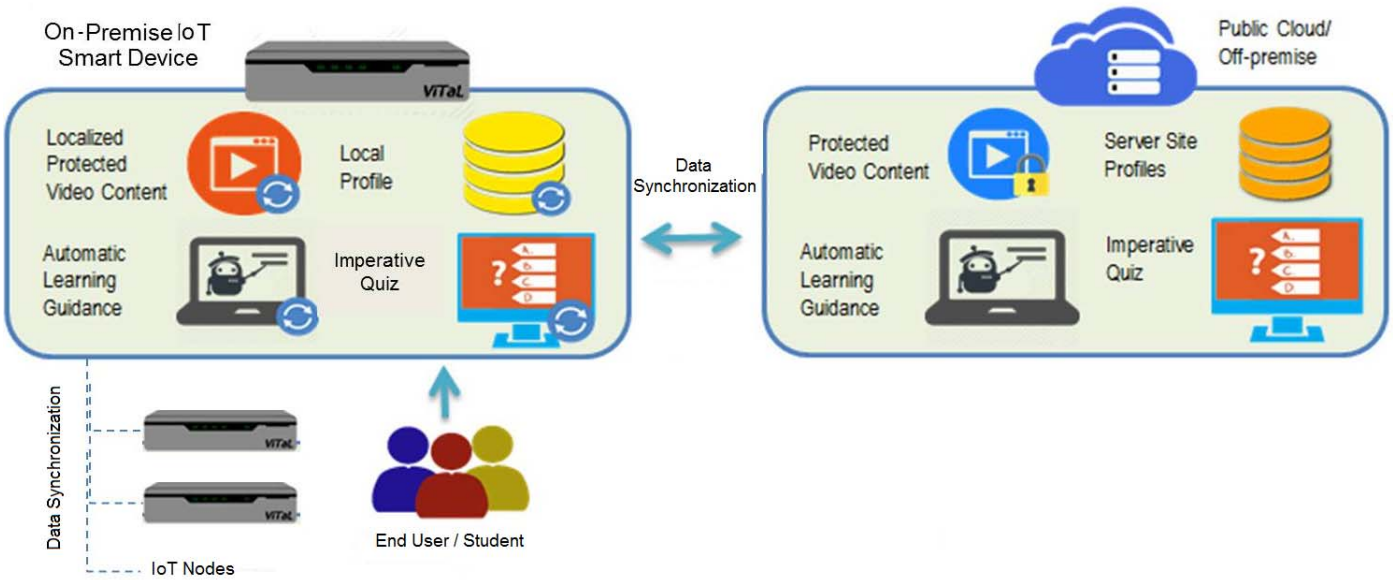


Fig. 4. The overall architecture

A peer node can request a learning content files from other nodes. The previous work on developing application based on P2P connectivity used the special nodes for facilitating peer-review of content [1]. P2P facilitates standards-based search and retrieval of learning objects across a heterogeneous network of peers.

In client/server or CDN systems, the learning contents are located in centralized or distributed databases. End users perform search and discovery to retrieve relevant items from specific server sources. In the P2P network the assessment items are treated as a reusable learning content and does not fully rely on the centralized repositories. The retrieved learning objects is aggregated and sequenced into courses for consumption on student's devices along with the distribution mechanism. Figure 2 illustrated the situations

C. IoT Smart Devices

The IoT smart devices are lightweight and low cost physical devices equipped with a processor, memory storage, local content hosting and synchronization engine. The device is able to alternately change from standalone device mode and to become a connected device mode for content sharing via P2P or internet connectivity. Thus the content can be accessed locally, or perform content request from other devices or from the public cloud server once the internet is available. Unlike the current CDN implementation, IoT smart devices are not fully dependent to the cloud server to distribute the learning content. It used local access capability or P2P communication during internet unavailability. Thus, student can access the learning content even in limited or non-existence internet access in geographical area. Figure 3 shows the framework design of the IoT smart devices.

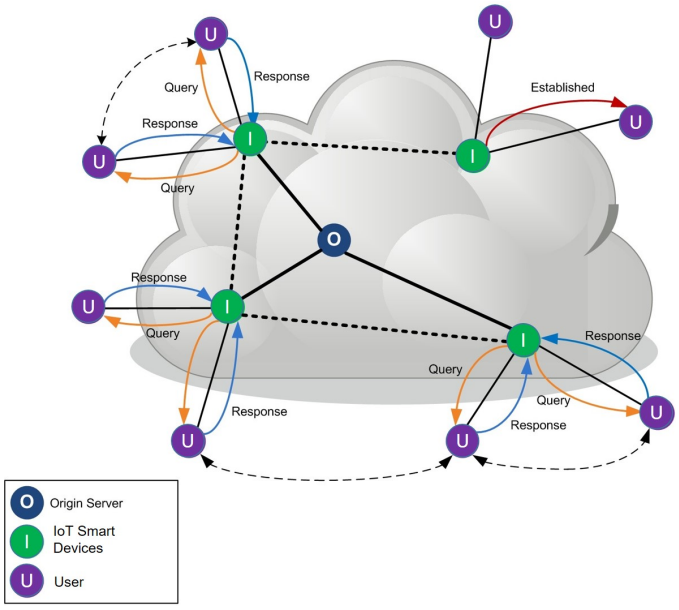


Fig. 3. The framework of IoT smart devices

IV. System Architecture

As shown in Figure 3, the overall architecture of the learning platform has been developed using the technologies mentioned above. Several IoT smart devices (shown as green node in Figure 3) with interconnection were adapted inside the architecture. The IoT smart devices serve as a server that holds the learning materials. Those IoT smart devices are connected to the main public cloud server for updating the latest learning contents. The learning contents are then distributed through each of the IoT smart devices, and provide the access to any

student or client devices such as laptop or mobile phone that connected on it. The following sub-sections describe the main technologies used in the architecture.

A. *Content Origin in Public Cloud Server*

Decentralized architecture using IoT smart devices require updated content existence in public cloud server as an origin source. The learning contents including learning video, learning guidance and exercises are uploaded to the server, while waiting request from nodes for replicating the content.

B. *IoT Smart Device as Distributed Nodes*

IoT smart devices are enabling value for sharing content on a peer to peer decentralized network and providing local access. The smart devices act as distributed nodes to perform control function for data synchronization of the participant's actions. The solution provides inherent scalability of mass numbers of endpoints. Figure 4 shows the overall architecture of learning content distribution.

C. *End User Content Access and Profiles*

Each user located at the end of each connected graph in Figure 3 is able to access learning content from IoT smart device by connecting their computers through WiFi connectivity. All learning activities are stored in local profiles, replicating to the public cloud server and to other smart devices as well for verification.

V. System Design & Implementation

In this experiment, the system run in full autonomous mode as illustrated in Figure 5. First, administrator will upload the learning content such as learning video content, learning guidance and quiz onto the main server on the cloud. The IoT smart device that is on the network will trace the content changes in the main server. Once the device found that the server contains new updated learning resource, it will perform synchronization with the main server, by downloading and create another copy inside the local memory of the device.

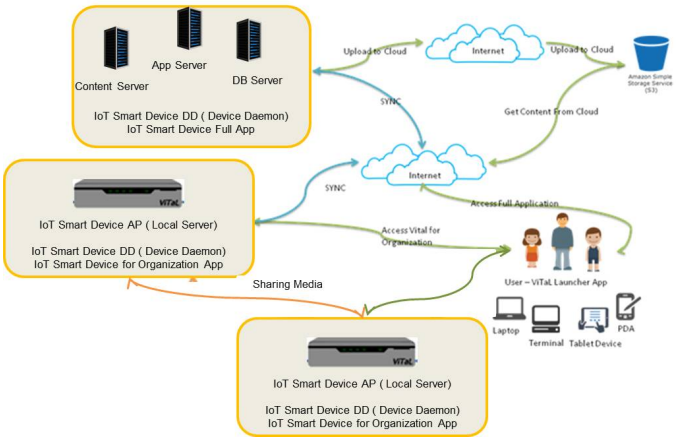


Fig. 5. The overview of the system implementation.

Through the P2P technology, other IoT smart devices which are connected within the same network (with or without internet connection) can share the learning resource among each other. Once any device update a new learning resource from main server, other devices will be able to synchronize the resource data on to their own local memory as demonstrated in Figure 6.

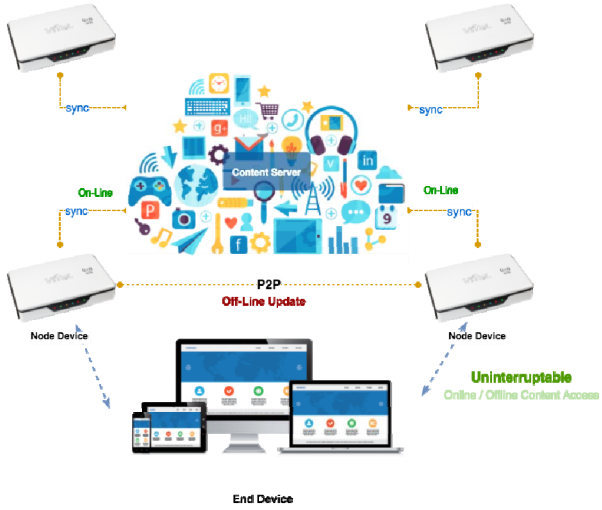


Fig. 6. The devices are uninterruptable by internet connection.

To prevent traffic overloading, CDN technology is used to spread the traffic along multiple IoT smart devices. Each node will be assigned to other nearby node if the current connected node is found to be overloaded with user. To access the learning resources, user can connect to any devices using any smart devices such as laptop, mobile phone and tablet.

The smart devices are implemented using ARM processor with a CPU speed of 1.2 GHz running Linux operating system equipped with 1 GB RAM and extendable memory storage. The connectivity of the smart device by default comes with a Fast Ethernet connection that can be upgraded to Gigabit connection (Ethernet or WiFi) capable of supporting up to 300 Mbps. In contrast to a conventional CDN servers, the smart device are much cheaper and can be deploy in an ad-hoc manner in a large quantity.

VI. Discussion and Conclusion

A single centralized server delivering contents to a massive number of users, although provides the cheapest solution has an obvious bottleneck once the number of users exceeded the server capacity. CDN on the other hand capable or improving user experience on the premise of delivering the content from the nearest server to the end users. CDN also in general are optimized based on the content type in order to deliver the content to the user in the most efficient manner. By offloading the traffic from the origin server to a multiple strategic geographical locations, the latency of delivering the content is significantly reduced. However, these servers are pre-deployed and immobile where the service providers must

carefully choose the location which in turn would result in a high cost. As a result, scaling the network is not cost effective. Traditionally, e-learning users are confined within their learning institutions where deploying CDN servers close to these institutions are sufficient in guaranteeing a satisfactory user experience. However, today learning ecosystem require the content to be delivered almost everywhere and in some cases where Internet connectivity is limited. Using smart device in delivering the content to the end users aims at providing a scalable network at a cost effective rate due to the low production cost of the device as well as its mobility. In other word, these smart devices act as a last mile content providers capable of delivering the content to the end user by physically being as close to the users as possible. Consequently, the user experience in terms of access time, cost and flexibility in delivering the content can be significantly improved.

In summary, the learning technology via web and cloud services has dominated learning ecosystem nowadays that brings a lot of potential usage on media rich learning materials. Accessing these large sizes of learning media files such as video-based educational materials has become a main obstacle for implementing the technology in certain condition. Student who live in places which are not having internet access or with insufficient bandwidth of internet such as in rural areas may not get a chance to fully utilize the learning technology. In this paper we introduce an IoT smart device for e-Learning content sharing based learning platform consisting of IoT smart devices set as local nodes for providing hybrid cloud services including on-premise service, peer-to-peer communication between the nodes or other smart objects, sharing and synchronizing media to or from public cloud service. The platform provides flexibility on mobilizing the nodes, where the smart device can be located on several different places for media and profile update, and bring to the targeted area for communicating with other local nodes. In conclusion, by adapting the CDN concept and P2P technology, the proposed IoT smart device for learning content sharing in hybrid cloud environment is able to provide a cost effective and a better learning environment solution.

ACKNOWLEDGMENT

We would like to express gratitude to the editor and reviewers for helpful suggestions and Universiti Teknologi Malaysia for sponsoring this research by the C-Flagship (Grant Number: Q.J130000.2428.02G27).

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