Rich Immersive Sports Experience: A Hybrid Multimedia System for Content Consumption

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***Abstract*—Recent widespread use of multimedia-enabled devices has prompted the industry to look at systems which can provide a distributed, synchronized content consumption experience. Motorola has partnered with Purdue University's eStadium project to create the Rich Immersive Sports Experience (RISE) project. RISE is an attempt to design and develop such a system geared toward use in suites in Purdue's Ross-Ade football stadium. The core of the system is Motorola's Media Bundle technology that represents content and timing information for the TV screens and smart phones used in the system. This paper discusses the design process for the RISE system, how Media Bundles are used, and our solutions to issues of synchronization, speed, reliability, and scalability.**

I. Introduction

The proliferation of devices capable of advanced multimedia delivery in recent years has prompted interest in multimedia consumption systems that are integrated across those devices. As more information and media becomes available about similar topics in a wide range of formats, the multimedia industry has begun to investigate how users can seamlessly utilize several formats simultaneously to experience events.

American football and large sporting events are categories that lend themselves readily to integrated multimedia consumption. In a typical American football game, multiple streams of simultaneous data, e.g., live video, instant replays, and game statistics, are being generated.

Traditional content delivery systems such as TV broadcasts and large video boards follow a "one size fits all" centralized paradigm, thus limiting the user experience to what the TV program directors think most users want to see at a given time. This approach is becoming more and more at odds with the following important emerging user expectations for systems that provide content consumption. New systems must:

- help users find and consume content related to the current experience from the Internet,
- make content available on any device that is convenient to the user,
- connect users to their communities, and help them share content with friends,
- show only targeted advertisements rather than blanket all users with the same message.

In this paper we propose the *Media Bundle* (MB) paradigm that helps content providers address these user requirements and lets them offer a richer experience. We describe a system that we have created at a stadium that lets users seamlessly access data related to the current game from different devices.

This system aims to make game data available to users in a structured way without overwhelming them. The system also needs to be scalable to tens of thousands of users in the stadium and automate content generation as much as possible. We describe how our system meets these constraints.

A. The eStadium Project

Motorola's Applied Research & Technology Center has partnered with the eStadium project at Purdue University which provides an excellent testbed for hybrid multimedia consumption [1].

eStadium, which was launched in 2001, is a partnership between Purdue's Center for Wireless Systems and Applications (CWSA), Information Technology at Purdue (ITaP), and Purdue Intercollegiate Athletics. The project provides a unique service to Purdue football fans as well as a real-world research and learning environment – a *living lab* – for CWSA researchers and students. The original eStadium application provided information such as concession stand menus, live statistics, and a utility to find nearby restaurants and hotels, among other features. In 2001, eStadium became the first such system to deliver instant replay videos wirelessly to mobile devices during football games via a WiFi network deployed at Purdue's Ross-Ade stadium [2] [3]. eStadium continues to improve and expand its repertoire of tools and services by gathering user feedback, following up on users' suggestions for new applications, and pursuing innovative research initiatives [4].

B. Collections of Related Content: Media Bundles

Users have a desire to discover and consume topically related content [5]. For example, users may want to follow how a news story developed over the course of days or they may simply want to watch all content related to their favorite sports team. This functionality is enabled by describing related content as a relationship graph that we refer to as a MB. MBs

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form a compact representation of topically related content, associated metadata, and relationships between content items. The nodes of a MB graph contain metadata about specific content contained in the media document pointed to by that node. Note that MBs do not contain the actual media data, but only links to the data. The edges in the MB relationship graph represent different types of relationships between the nodes. Since many types of relationships are possible between content items, usually there will be more than one edge between two nodes in a MB.

C. The Rich Immersive Sports Experience Concept

A proposed next generation component of the eStadium system is an event experience that provides a rich collection of data about the ongoing game and lets users modify the consumption experience to their needs, which we refer to as the Rich, Immersive Sports Experience (RISE2.0). RISE2.0 utilizes the MB paradigm developed by Motorola as the underlying technology to deliver collections of topically related data to devices.

The goal of RISE2.0 is to provide additional content to attendees in the suites in ways that exploit various types of devices to improve the overall user experience. The available devices are one television per suite and one WiFi-enabled smartphone per person. A user analysis was developed which led to definitions of potentially useful applications which are supported via the Media Bundle paradigm.

II. User Groups and Interfaces

A. User Groups

Based on our observations from previous years in eStadium, we have classified the users in the suites into three categories.

1) Apathetic Alan: Alan's defining characteristic is an indifference to advanced technological systems, such as RISE2.0. The key to reaching this group is to provide a passive consumption experience that requires little or no interaction which, once implemented, will be missed if it is taken away in future games. We estimate this user group to be approximately 80% of in-suite users.

2) One-Feature Frank: Frank's defining characteristic is that he will not be overly excited by new technology, but is willing to interact with it to find one feature that he would use from time to time. Having a variety of applications, each of which would be useful to a typical football fan, will be the key to reaching this group of users. We anticipate that approximately 15% of in-suite users fall into this category.

3) Technology Teddy: Teddy is the power user of RISE2.0. He wants a heavily interactive system which allows him to demonstrate his technical prowess to the rest of the fans in the suite while simultaneously providing him with infotainment that he is not able to get any other way. We anticipate that approximately 5% of users fall into this category.

The relative percentages stem from the following analysis. The eStadium system currently averages 466 unique users during the 2008 football season. Of these users, we have found via informal user studies and device loaning programs that about 25% are classified as Technology Teddy, and about 75% of these users are classified as One-Feature Frank. It is well known that average stadium attendance is roughly 60,000 people for most Purdue home games, and of these 60,000, internal marketing reports estimate the number people with devices and plans capable of viewing eStadium content at 40%, which is a potential market of 24,000 users per game. Marketing for eStadium has been thus far limited to primarily the clients in the higher-end seats, which means that only about 10% of possible users know about eStadium, or 2,400. Since the 466 average users per game encompasses Technology Teddy and One-Feature Frank users, that puts the overall estimates for Apathetic Alan at roughly 80%, One-Feature Frank at roughly 15%, and Technology Teddy at roughly 5%. We assume that the distribution of users in a given suite follows these guidelines in general.

B. Applications and Features

To appeal to the user groups described in Section II-A, several applications were conceived.

1) Passive Stream: The RISE2.0 system's basic level of operation for a user is the passive stream. The passive stream is a set of content items that are shown on all devices if the user is not interacting with the device.

Currently the passive stream consists of a few webpages with basic information that the majority of users will find useful, such as game statistics, other game scores, weather, and advertisements. The phone will cycle through these pages using a circular queue. The TV screen has similar queues controlling the areas of the GUI described in Section II-C1.

2) Interactive "Passive" Stream: At any time during the passive stream, the user can "pause" the cycle on the phone and view the content items at their leisure. For example, a fan interested in game statistics could tap the "pause" button to better analyze the statistics page, and return to passive mode either explicitly through a "play" button or implicitly through a timeout function. There are also forward and backward buttons to cycle through the passive feed's items.

3) One-Click Buy: A special portion of the TV screen will be dedicated to advertisements that correspond with an advertisement shown on the phone as one item of the passive stream. The advertisement on the phone provides the ability to purchase the item being advertised within one or two clicks. The advertisement is shown on the TV at the start of the passive stream on the phone so users have plenty of time to see the advertisement on the TV before it appears on the phone to purchase.

4) Drive Recap: The drive recap feature of the RISE2.0 system is a back-to-back set of all the plays in a drive. A drive is a consecutive sequence of plays in which the same team has possession of the ball. It consists of a set of video replays shown on the TV's main screen and the highlighted drive visualization image (Figure 1) for that play being shown simultaneously on the phone. The user has the ability to add a play to their "My Highlights" bundle while it is playing in the drive recap to be used for later viewing.

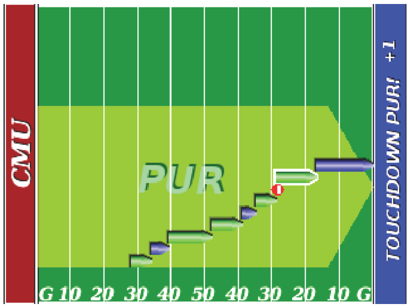

Fig. 1. Highlighted drive visualization image. Each arrow represents one play in the drive. The play outlined in white is the one playing currently on the TV.

5) Remote Control: For the users who resemble Technology Teddy (described in Section II-A3), there is a “Remote Control” function which allows them to play previous drive recaps and plays, their “My Highlights” bundle, additional game information, and potentially add customization to their suite’s RISE2.0 system.

C. Device User Interfaces and Applications

The RISE2.0 design concept was user-driven in the sense that we designed the graphical user interfaces (GUI’s) first and then designed the back-end system to support the interaction provided by the GUI’s. The GUI designs define how the three user groups from Section II-A will use the applications described in Section II-B.

1) Television GUI: The GUI displayed on the TV screen has a border on the top and right-hand side of the screen, with the rest of the space being the main video area, as shown in Figure 2(a). The top border contains all basic game information like team scores, time remaining, and play position. The right border also has two areas for content to be displayed. The current system uses one area for showing advertisements, and the other area for showing the current play’s highlighted drive visualization image. The main content area is intended for live game video and replay videos.

2) Phone GUI: The phone’s GUI was designed for a Windows Mobile device with a 2.8 inch portrait screen, as shown in Figure 2(b). The passive stream screen shows the items of the stream (webpage or image) and has three small buttons at the bottom of the screen for pausing and going to the previous or next item. All video replays on the TV have a corresponding drive visualization image that is shown on the phone highlighting what happened in that play. Users have an additional button during plays allowing them to add that play to their “My Highlights” bundle for later viewing.

The phone also has the remote control application, described in Section II-B5, which consists of unique and easily identifiable icons for each feature they represent, as well as a 1-2 word feature title underneath the icon. Pressing the icon will perform the requested feature.

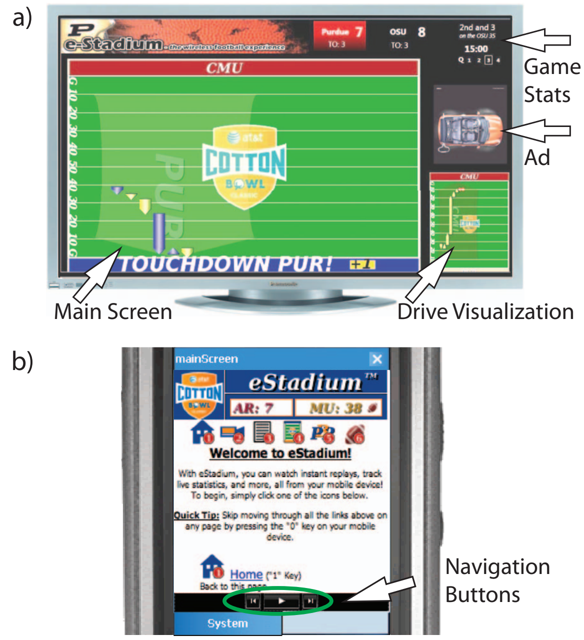

Fig. 2. a) Television GUI. b) Phone GUI on the Motorola MC35.

III. System Design Issues

A. Director

The purpose of the director is to enable a human overseer to control everything that is shown on the system in real time. The director is envisioned to act much like the director for large video display boards in stadiums. The director has the ability to control any content being displayed on the system including drive recaps, promotional videos, advertisements, and more, and the director can adapt this to unpredictable events in the game.

Much of the director’s work can be handled automatically. For instance, the system has the information as to when a drive ends and which videos and plays were part of that drive. Therefore, the director can simply press one button to initiate the drive recap application and can also easily remove uninteresting plays from the list of plays, if necessary. The director can also modify the content in the passive stream to update it for changing game conditions such as displaying an advertisement for raincoats if it starts to rain or sweatshirts on a cold day. There is even the ability to synchronize advertisements and other content with what is currently being shown on the large video board in the stadium.

The structures discussed in section III-C also enable a director to create content and display information before the game begins, which can be enabled at a given time to simplify tasks that can be handled beforehand.

B. Media Bundle Design

The basic premise of a Media Bundle is to provide a powerful means of describing content and relationships between individual pieces of content. For example, a news story on sun tan lotion on a particular website and a video of a news report on deleterious effects of prolonged sun exposure would be examples of content, and a link indicating they are both about exposure to sunlight would be an association between them.

Along these lines, the Media Bundle paradigm defines three components which correspond directly to classes in the API, each of which are assigned a *globally-unique identifier* (GUID) to distinguish them:

- Content Item: this represents a single piece of content which has a *universal resource locator* (URL),
- Association: this is a list of GUID's of content items or other associations which allow for hierarchically larger sets of recursive relationships to be developed,
- Bundle: a bundle is a special kind of an association which acts as a container for all associations and content, enabling efficient representation and distribution via XML.

All of the above items have a (possibly empty) list of metadata which is simply a set of user-defined key-value pairs. To use the previous example of a sun tan lotion article on a website, its metadata may include the URL for the site, an indicator that it is a webpage, and its author. The television report may have metadata such as the channel, time of airing, and reporter name. The association between them might have a metadata key of "type" with a value of "sun."

The Media Bundle API also provides functionality to combine bundles which enables incremental network transfers. A new bundle can be created which is similar to a previous bundle, and a difference bundle can be generated. This is pushed to client devices where a "patch" function can apply the changes to an existing prior bundle.

C. Content Bundles and Timing Queues

Media Bundles have enabled us to uniquely solve two significant challenges presented by a distributed multimedia consumption system. The first challenge is that of content representation and distribution. The eStadium system is generating many types of content throughout a game including play-by-play text, drive identification, instant replay videos, etc. This is conveniently represented as individual content items in an ever-changing *content bundle* (CB) via simple PHP scripts that convert the source data from eStadium into new content items and associations.

The second, more complex challenge, was to create a means of representing and synchronizing the times that the items in the CB should be displayed. We used a set of priority queues to solve this problem: one circular queue to represent the passive stream, one *first-in-first-out* (FIFO) queue for Director-created content, and one FIFO queue for user-generated content created via the remote control, as shown in Figure 3. The system chooses which content to display by first checking for any content in the highest priority queue. If that queue is empty it will then look for content to display in the next queue, until it reaches the bottom circular queue which always has content. This set of priority queues is easily represented as a *timing bundle* (TB), where the content items are the GUID's of associations or content from the CB, and the associations are each of the queues with metadata about when to play each item.

This representation has become extremely flexible as our implementation details have evolved. For example, we decided to represent the passive queue's circular nature via modulo arithmetic based on the number of seconds this set of queues has been active. This involved simply changing the value of a piece of metadata in the TB.

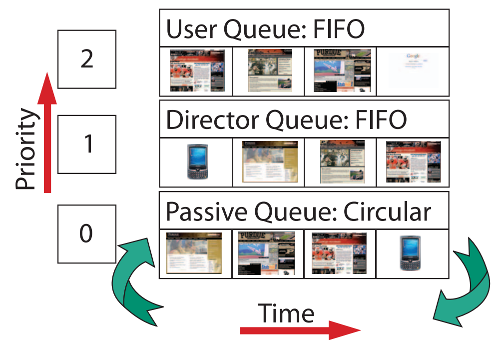

Fig. 3. Priority queue system.

Another example of the flexibility of the Media Bundle approach is the display of rotating advertisements within the passive queue. The intent is that the passive queue will have a single slot in which an advertisement will be shown. However, this advertisement needs to rotate among several advertisers over time. The initial flat nature of the circular queue meant that we had to repeat the static content in the queue, interleaved with the changing ads. We alleviated this problem by allowing recursive collections of content to occupy a single slot of the bottom level queue, as shown in Figure 4. The recursive nature of the Media Bundle's API easily supported this change as well, with the only development requirements residing within the timing subsystem itself.

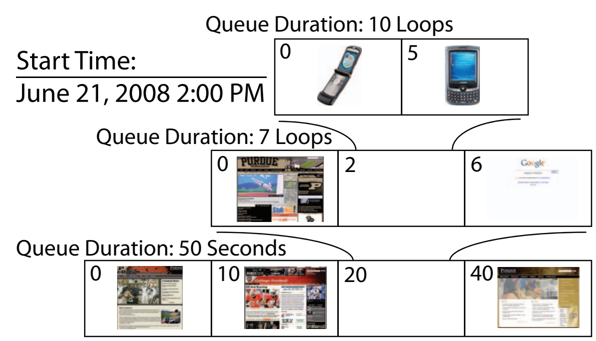

Fig. 4. Each item in any level of the circular queue can be another circular queue or a content item to play.

D. Network Issues

The devices involved in RISE2.0 are the director's computer, the bundle server, the television controller, and the multitude of handheld smartphones, as shown in Figure 5. It is assumed that the television, smartphones, and server will reside on the same subnet, although various modifications are possible to remove this restriction. The director's computer, bundle server, and television controller will have wired network connectivity, and the phones will be connected wirelessly to a router in the suite.

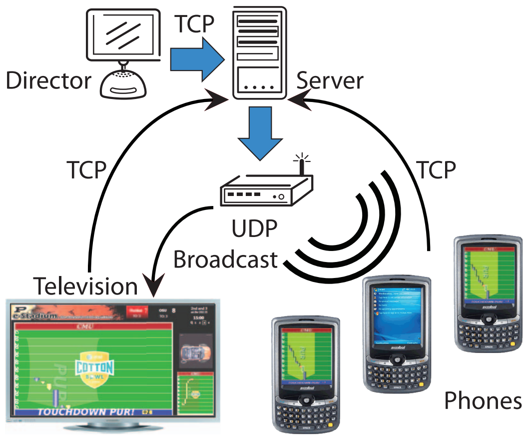

Fig. 5. RISE2.0 network diagram.

The network communication timeline is shown in Figure 6. First, the director software generates a bundle. This bundle is transmitted via a standard TCP-based connection to the bundle server. The bundle server examines its database for the last bundle sent, and compares it with the new bundle to generate a difference bundle. The difference bundle is assigned a sequence number and then sent to the devices via a single UDP broadcast. The existing bundle on the client is "patched" with the received difference bundle. Should any device receive a corrupted bundle, receive a sequence number out of order, or simply be turned off and turned back on, it will send a TCP-based request to the server to resend the last full bundle. The server will then respond with another UDP broadcast of the full content and/or timing bundle. The broadcasting of error messages alleviates scalability issues via the broadcast method in that only one error message need be sent in order to fix the entire system, rather than requiring error messages from all devices.

IV. Future Work

Since the RISE2.0 system is currently in active development, our first goal is deploying a demonstration version of the system at a Purdue home football game in the upcoming 2008-2009 season. The deployment will provide valuable opportunities for user testing, both in validating our choice of user groups and in identifying usage patterns in a distributed multimedia consumption system. Additionally, since all phones will likely be requesting the same content at the same time due to the nature of the passive stream, significant network bandwidth restrictions can be overcome via broadcast-based pre-downloading of content items. Upcoming advances in the eStadium project overall, such as increased fan-video board interaction, safety and security systems, and other applications, will provide many new opportunities as well.

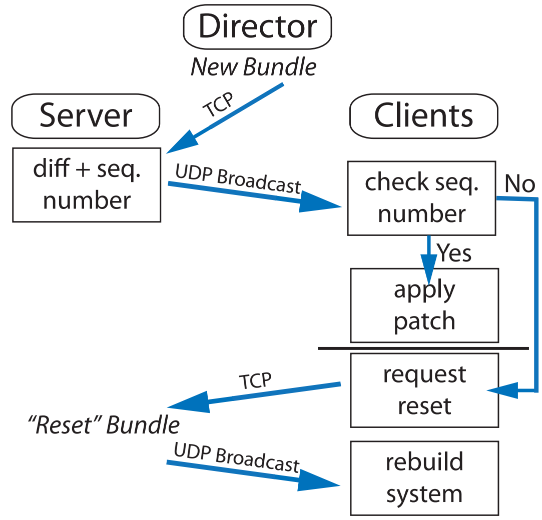

Fig. 6. RISE2.0 network communication timeline diagram.

V. Conclusion

The goal of the RISE2.0 project is to develop an immersive, distributed, multimedia consumption system to improve the in-suite experience at Purdue University home football games using content from the existing eStadium system. Many design challenges have been overcome thanks in large part to Motorola's Applied Research & Technology Center's Media Bundle paradigm which was used in the representation of content, relationships, and timing information. The design decisions and some implementation details were discussed here, and our solutions to issues of synchronization, speed, reliability, and scalability were presented.

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