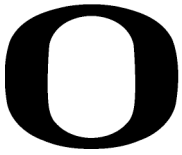

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The Role of Middleware in Mobile Device Content Delivery

CAPSTONE REPORT

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Abstract

Middleware has an important role in connecting distributed mobile systems. According to Grigoras (2006), mobile middleware provides transparent access to proprietary services and resources in a cost effective way. Delivering content to mobile devices requires understanding (1) mobile architecture strategies, (2) the role of middleware, and (3) the ability to reuse existing content through adaptation. This literature review describes software and technology trends that address issues and limitations concerning mobile devices and content delivery.

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Introduction to the Literature Review

Topic

The purpose of this literature review is to describe how content is adapted for delivery to mobile devices. The focus is on (1) mobile architecture strategies, (2) the role of middleware, and (3) the ability to leverage existing investments in content management for delivering content to mobile devices.

Topic Description

"A mobile device is a pocket-sized computing device, typically comprising a small visual display screen for user output and a miniature keyboard or touch screen for user input" (Wikipedia, 2007). There is an increase in the demand to deliver content to mobile devices, however these devices and the systems which manage content have limitations as to how they can interact, display and deliver new and existing information (Jain, Puglia, Wullert, & Bakker, 2004).

In addition to the device limitations, information has been created in formats that are not compatible with the growing number of devices in use. These formats must be transformed in order to be effective on mobile devices (Hinz, Fiala, & Wehner, 2004). To address these limitations, middleware and content transformation services are deployed to adapt content formats and services according end devices capabilities, bandwidth limitations, and locations (Jain et al., 2004).

Format and device limitations can be addressed using middleware and device specific transformations of the content (Gaedke, Beigl, Gellersen & Segor, 1998). Middleware and content transformations adapt and deliver content by leveraging existing content and information management systems (Gaedke et al., 1998). For example, Sun Microsystems and Bell Mobility partnered to use Sun's software and middleware to adapt and deliver content and applications over Bell Mobility's network to mobile content consumers (Sun, 2005). The partnership allows Bell Mobility to deliver existing content, already under management, over their current network, to existing subscribers, without having to rebuild their systems from the ground up (Sun, 2005).

Research Problem

Wireless technology provides great value to businesses when it allows employees and customers to access real-time data to make timely decisions that either decrease costs or increase revenues (Frolick & Chen, 2004). Leung and Antypas (2001) define m-commerce and m-business as both content delivery and transactions on mobile devices. The majority of current m-commerce and m-business is based on the idea of combining the growth of the internet and the emerging mobile communications facilities to conduct business and provide a new platform to facilitate commerce. (Hacklin & Backholm, 2002) Popovici et al., (2003) argue that businesses need to grow and adapt their services and content to the growing number of mobile device available on the market today. The question then is: How do businesses provide access to information seamlessly across multiple technologies with advanced value-added features, at an acceptable cost (Jain et al., 2004)? The research presented here considers the use of middleware to be a solution to this problem.

This literature review is designed to direct information and technical managers to a set of published references which describe the software available and the trends in technology to address the known issues and limitations of mobile devices and content delivery. This literature provides an understanding of ways to reuse existing information for mobile delivery and leverage existing investments in content management and content platforms. Additionally, the review incorporates resources which allow the managers to plan for future content management and how to organize and tag content for more efficient delivery to mobile devices at lower costs than rebuilding the infrastructure and the business they support. Mobile devices and mobile content delivery techniques have matured quickly and it is important to have a reliable collection of references which focus on adapting content for different devices and the role of middleware in adaptation and leverage of available content systems (De Virgilio, Torlone & Houben, 2006).

Adaptation of Content

Content, from the perspective of media and publishing, is information and experiences created by individuals, institutions and technology to benefit audiences in context it is intended for (Wikipedia, "Content," 2007) , in this case mobile devices. It is important to note that during this review the word "content" refers to both content that is read on device displays by users and content read by software and hardware applications such as configuration files. Several restrictions influence how content can be delivered: computing power, display properties, communication protocols and content format (Gaedke et al., 1998). To consistently deliver existing information to all the available mobile devices requires the conversion of content and the adaptation of services providing the connection (Jain et al., 2004). The two approaches Hinz

et al. (2004) have identified to adapt content have also been described by Gaedke et al. (1998) as dynamic and explicit. Dynamic is defined as the automated method to adapting content based on rules. Explicit is interpreted to mean static content formats, adapted using specific description languages that have been designed for content delivery to mobile devices (Gaedke et al., 1998). The dynamic method of adaptation of existing content or applications is automated using middleware services and standardized information architecture (Hinz et al., 2004). The alternative to automated or dynamic conversion is development of 'explicitly' adapted content for each platform. Explicit adaptation often requires replicated and wasted development effort and maintenance to rebuild and manage information in all the specified formats (Gaedke et al., 1998). The explicit method may be more accurate but comes at a higher cost to develop and maintain than automated conversions, and only supports the limited formats explicitly defined (Gaedke et al., 1998).

Using standard formats for content and including middleware in wireless system architectures can solve these problems (Hinz et al., 2004). Middleware services can take data and transform them into a specific device formats on demand (Hinz et al., 2004). Dynamic adaptation middleware applications consider presentation space characteristics and limitations at a cost that is lower than regenerating and managing the content using an explicit adaptation scheme (Jain et al., 2004). "The [dynamic] approach relies on two basic notions: the profile and the configuration. The later describes in abstract terms, how to build the various levels of web interface (Virgilio, Torlone & Houben, 2006)." By relying on the profile and configuration properties to define how to adapt the content, new devices can be added and the content can be easily transformed for any new device. According to Virgilio, Torlone, Houben (2006) and Hinz

et al. (2004), if the content is adapted dynamically, businesses can benefit from increased efficiencies in development and maintenance as well as a decrease in format limitations and costs.

The Role of Middleware

Middleware is defined by Grigoras (2006) as "a set of services placed between the applications and the operating systems" (p.2). Middleware allows access to existing information from businesses and content providers, and adapts content to specified formats for different devices with different media requirements and device limitations (Jain et al., 2004). The integration of middleware services and standards promotes formats such as WAP, XML/XHTML and i-Mode; standardization enables businesses to overcome device and format limitations (Grigoras, 2006). Mobile middleware provides transparent access to proprietary services and resources in a cost effective way (Grigoras, 2006). The ability for middleware to recognize devices derives from a list of devices and profile information about the devices that identifies specific properties (i.e., the strengths and weaknesses) of the device (Jain et al., 2004). The research presented here addresses the role of middleware and how to maintain a list of devices, device properties and the benefit to the overall content adaptation service.

Leveraging Investments in Content Management

The assumption underlying this review is that the value of middleware, with respect to efficiency and cost, is the ability to leverage existing investments in content management. Middleware is sometimes called a 'glue' technology, because it is used to integrate heterogeneously distributed components and make those components interoperable (Vaughan-Nichols, 2006). This means that a component on one system can access a component on another system (Guo, 2006). With the integration of middleware the different types of heterogeneous components can act as a single homogenous system that allows a system to be constructed through integrating legacy and commercial off-the-shelf components with newly built components (Guo, 2006). Guo (2006) suggests that it is better for businesses to adopt this integration approach than to develop a specialized language or proprietary architecture that requires larger investment and may entail unacceptable risks (p. 34). According to Guo (2006), it is the integration of middleware which utilizes existing technologies that provides the economic and efficiency benefits to businesses.

Audience and Significance

There are many individuals and businesses that can benefit from an understanding of the information and solutions presented in the literature reviewed in this work, most specifically, managers and technicians who are responsible for the creation of middleware and mobile content solutions. The m-business and m-commerce audiences seek to expand their presence and delivery capabilities via mobile devices (Leung & Antypas, 2001) and will thus benefit from this collection of resources. Information managers, technical leads and architects design solutions to address problems caused by the large number of mobile devices and the limitations of these devices to access and display content (Popovici, Frei, & Alonso, 2003). Technical and

information management professionals can refer to this information when considering how to leverage investments in content management, middleware components and content delivery applications (Popovici et al., 2003).

However, making the 'best' choice in any given situation for a content delivery method is not always easy. Numerous possible solutions for adapting web presentations and applications have emerged for mobile devices, including middleware platforms for mobile systems. This is in part due to the fact that middleware can take advantage of the deployed software infrastructure while providing clean high-level programming abstractions in languages already available today (Guo, 2006). As noted above, Hinz et al. (2004) have identified two main integral approaches to adapt or deliver content. The first approach adjusts existing web and application pages to the limited display and interaction capabilities offered by mobile devices (Hinz et al., 2004). The second approach requires rebuilding web and application pages 'from scratch' and considers device (and user) adaptation during the specification and implementation (Hinz et al., 2004). The research goal in this literature review is to provide information and technical professionals with an understanding of the aforementioned approaches as well as the role middleware plays in content delivery to mobile web devices. Until mobile devices mature to possess the same or comparable capabilities as PC browsers, managers and architects will need to heighten their understanding of content adaptation and middleware (Chakravorty, 2005) in order to make the best choice for their system needs.

Research Limitations

The number of scholarly articles referred to in this research underlines [number/underlines] the growing attention that is being paid to the topic of mobile content delivery. Using the search term "mobile content" restricted to the year 1998, the WorldCat database returned 5 references on the topic of mobile content compared to the 40 references available in the same database in 2006, and the 50 references available from WorldCat for the year 2007. The steady increase confirms the growing focus on mobile content. Within the field of information technology different systems have added middleware to extend their capabilities. The references chosen have a specific focus on middleware for mobile systems that adapt content and services for mobile devices in addition to the possible benefits of using middleware to transform content for mobile distribution. To maintain the research focus on these areas, a series of limitations have been applied to the results of the search effort to eliminate irrelevant information:

1) Excluded are references that do not address strategies for content adaptation using middleware to adjust content to mobile device limitations. These strategies are required to build solutions for reusing existing information assets and investment in content management systems (Maamar, Yahyaoui & Mansoor, 2004).
2) Excluded from this review are technical references where authors focus on network topologies and transmission protocols that are unrelated to the adaptation and delivery of content. The managers and technical audience of this information deal more with content transformation and middleware services, and are not concerned with network architecture information that is excluded.
3) Search Engines used to collect information on the most recent advances in industry products and trends include: Google Scholar, Science Research Portal, Microsoft Live @

Microsoft.com and Yahoo. The white papers on industry products and services are not included in those selected for use in the Review of the Literature, because they are not academic sources, but a few are used to provide a resource for readers to get some context for the application of the research material.

4) The time frame for search and selection of the sources included in Review of the Literature encompasses the years 1998 to the present year 2007. The topic of mobile content delivery and middleware had been researched prior to 1998; however, mobile devices have evolved significantly in connectivity and capabilities since the year 1998 and references on strategies for content delivery prior to 1998 are deprecated and no longer relevant (Kim & Le, 2005).
5) Specific related topics outside the scope of this review include:

    - *Push messaging:* Push messaging deals with newly created content and applications that were designed specifically for mobile devices. Middleware for push messaging systems addresses problems not related to the adaptation of existing content. Therefore, papers focused on push messaging were excluded to better focus the review.
    - *Middleware application development:* The process and techniques for developing the code for middleware applications is a broad topic and must address more technical application issues such as memory, processing and other software design or performance problems for components that are irrelevant to mobile content and adaptation.

Writing Plan Introduction

Leedy and Ormrod (2005) describe the literature review function as a way to look at what others have done in areas that are similar or that have research that is related. A literature review may reveal how others have handled methodological and design issues in similar studies (Leedy & Ormrod, 2005). The review may also reveal methods of dealing with problem situations similar to the issues addressed in the topic description.

Table 1: Thematic Outline

Theme 1. Adaptation of Content

- Dynamic Transformation
- Explicit Transformation
- Managing Device Lists

Theme 2. The Role of Middleware

- Architecture design patterns
- Handling Content Formats

Theme 3. Leveraging Investments in Content Management

- Content Reuse
- Delivery Protocols
- Page Segmentation

The structure of the content presented in this literature review addresses the two main strategies that have evolved to solve problems of mobile content delivery and the role of middleware in these solutions (Hinz et al., 2004). To meet the requirements of a literature review given by Leedy and Ormond (2005) the literature is presented thematically. The University of Washington Writing Center (2004) describes the thematic organizational approach as choosing an area of research, reading all the relevant studies, and organize them in a meaningful way. The three main themes, presented in *Table 1: Thematic Outline*, are developed in congruence with the University of Washington Writing Center's (2005) organizational approach. Each main theme is

elaborated by a set of sub-themes as noted and these sub-themes have relationships across different areas of the topic.

Definitions

The collection of definitions includes industry specific terms, technical concepts and complete definitions of acronyms. Not all the terms defined are contained in the literature review, however have been included to illustrate concepts included in the complete bibliography. The additional definitions are provided as a supplemental resource for the audience.

Adaptation Modules: Adaptation modules translate the markup languages and decompose the source web page into perceivable units (Jain et al., 2004).

Adaptivity or Dynamic Adaptation: The kind of adaptation included in the generated adaptive hypermedia presentation (Hinz et al., 2004).

CC/PP (Composite Capabilities / Preference Profiles): CC/PP is a mechanism through which a mobile user agent can transmit information about the mobile device (Hua et al., 2006). CC/PP is also a Resource Description Framework (RDF) specification for describing device capabilities and user preferences in a standard way (Zang, 2007).

Content: From the perspective of media and publishing [content] may be thought of as information and experiences created by individuals, institutions and technology to benefit audiences in contexts that they value (Wikipedia, “Content”, 2007).

Content Adaptation: Using software to re-authorize a web page through a series of transformations, including layout change and content format reconfigurations so that the page can be effectively displayed on a device and the user can interactively navigate the page (Zang, 2007).

Content Independent: Not being tied to or providing content itself but easily leveraging third party content (Jain et al., 2004).

Dimension: Dimension is a property that characterizes a profile. Each dimension can be described by a set of attributes (Lee, 2003).

Dynamic Content Adaptation: Content adapted dynamically is adapted on request and generated from a script requiring less maintenance of the content and allowing more focus on the logic which adapts the content (Gaedke et al., 1998).

Explicit or Static Adaptation: Refers to the adaptation process that is based on the available properties for the device that the user will utilize to access the generated presentation; the information is transformed and available before being requested (Hinz et al., 2004).

Flexible (with respect to content and devices): Allowing new software components to be introduced easily for new classes of services as well as new wireless media and devices; (Jain et al., 2004)

Hypermedia Presentations: Adaptivity supported by feedback mechanisms updating the user model according to the user's interactions with the presentation (Hinz et al., 2004).

Interface Definition Language (IDL): The interfaces defined in an IDL file serve as a contract between a server and its clients. Clients interact with a server by invoking methods described in the IDL. The service provided by a component is encapsulated as an object and the interface of an object describes the provided service, which is a set of method calls defined through an IDL (Interface Definition Language) (Guo, 2006).

M-business (mobile business): The extension of electronic business to mobile devices (Lee, 2006).

M-Commerce (mobile commerce): Leung and Antypas (2001) define M-Commerce as both "content delivery (notification and reporting) and transactions (purchasing and data entry) on mobile devices."

Middleware: A set of services placed between the applications and the operating systems (Grigoras, 2006). "The main goal of middleware is to facilitate component interaction of components. Component interaction covers component communication, collaboration, and coordination (Guo, 2006 p. 56)."

Mobile Device: A mobile device (also known as converged device, handheld device, handheld computer, "Palmtop" or simply handheld) is a pocket-sized computing device, typically

comprising of a small visual display screen for user output and a miniature keyboard or touch screen for user input. In the case of the personal digital assistant (PDA) the input and output are combined into a touch-screen interface. Smartphones and PDAs are popular amongst those who require the assistance and convenience of a conventional computer in environments where carrying one would not be practical (Wikipedia "Mobile Device," 2007).

Mobile Middleware: Mobile middleware is characterized as bridging between mobile technologies and computer communication (Hacklin & Backholm, 2002).

Modular: Allowing software and content components to be reused for multiple services (Jain et al., 2004);

Multiple Encoding: Storing multiple copies of the same content with different encoding methods or parameters so an application may dynamically choose the appropriate encoding format (Zang, 2007).

Page Segmentation: Page segmentation makes use of page layout features such as font, color, and size, etc., to separate semantically different blocks from each other. Based on a visual analysis of HTML elements it presents a useful page splitting algorithm that can effectively partition large Web pages into a series of tailored content blocks (Hua et al., 2006).

Profile: Profile is the description of an autonomous aspect of the context in which the web site is accessed that influences the way the content is presented (Lee, 2003).

Reflective Middleware: Opens the definition of the infrastructure and allows the dynamic reprogramming of the service layers, available in standardization projects – CORBAng (Popovici et al., 2003).

Transcoding: Transcoding is a method that changes data quality in order for applications to use the minimum amount of energy when processing it (Hua et al., 2006).

WAP: WAP is an open international standard for applications that use wireless communication. Its principal application is to enable access to the Internet from a mobile device (Lee & Lu, 2003).

Research Parameters

The preliminary research methodology is based on conducting exploratory searches in the literature to gain an understanding of the limitations and capabilities of mobile devices and the content available. From the questions developed after exploratory searches on the subject, a more formal strategy for research is developed based on key questions and the sub-topics relating to them.

Search Terms

References for the literature review are collected using the search terms and controlled vocabularies listed below. The search terms are mined from the analysis of literature found during initial searches.

Key search terms

- Smartphone content
- Hypermedia
- Mobile computing
- Transcoding
- Mobile Internet architecture
- Mobile Content Delivery
- Mobile Content Middleware
- Content Adaptation
- Mobile Workers
- Mobile Information Architecture

Subtopic search terms

- Mobile Delivery
- WAP
- WAP Middleware
- Mobile Content Design
- M-Commerce
- M-Business

Search Record

Table 2 below presents the format used to document the searches conducted and the rationale for excluding specific search engines, indexes, and libraries and specific details about the number of results. The actual documentation is located in Appendix A. The columns of the table are included because of the relevance they reveal about each search engine or database and the overall quality of the results.

Table 2: Search Documentation Format	
Search Engine/Database	Names of the different search applications used to located references.
Search Terms	Word or words used as parameters for searching the repositories of information.
Results	Total number of results returned for the Search Engine/Database using the specified search terms.
Quality of results	Results are rated as Poor, Average, Good, and Excellent based on the number of relevant results returned for a given query.
Notes	Notes about the results and the search terms. If the results are not used, notes about how spending the time to read the results added context to the overall reference search.

Evaluation Criteria

The final compilation of references in this review is the result of a combination of approaches to evaluating the literature. In addition to the methods suggested by Hewitt (2002), a supplementary set of criteria is added specific to the topic and the key terms used. Hewitt (2002) suggests scanning the abstracts and other high level headings including the tables, figures, conclusions and reference lists, and looking for any obvious omissions in the presentations and figures. Hewitt's suggestions are helpful once a set of results is obtained and those results are collected using search engines, databases, journals and industry resources. The following is a brief description of the strategy and results of the searches conducted using each of the resources. The bibliographic information for academic papers that focused on middleware architecture and the pros and cons of middleware integration is documented and saved in order to expand the breadth and depth of this research. The results of key word searches using the search applications and databases are scanned for relevant titles that include the terms "content" and "middleware". From the collection of search results that are saved the abstracts and tables of contents are examined for relevant themes including content adaptation and the delivery of adapted content to mobile devices. Finally, the remaining search results are compared against Table 1: Thematic Outline, to determine if the resource has a topic relevant to the overall theme of the literature review.

Search engines.

Literature was collected from search engines using the specified search terms. Search Engines used include: Google Scholar, Science Research Portal, Microsoft Live @ Microsoft.com and Yahoo. Google Scholar and the Science Research Portal produced peer reviewed academic

research and articles while Microsoft and Yahoo are good search engines for current industry products and trends. The white papers on industry products and services are not explicitly used in the literature review but provided a place to find relevant search terms and diagrams of mobile middleware architectures.

Databases.

Research information was obtained from the following databases: LexisNexis, Academic Search Premier and WorldCat. The databases have many different areas of focus and the broad number of topics in the databases helped to branch off searches using the different key words found in the references.

Journals.

Information for use in the review of the literature was obtained from the following journals: IEEE transactions on mobile computing, Mobile Communications, Mobile Communication Report, Mobile Matters, Sage: Journal of Information Science, Sage: Bulletin of Science, Technology & Society.

The Journals are found using controlled vocabulary/taxonomy starting from the UO Library: Subject > Information Technology > Mobile Computing.

Additional literature resources.

Additional resources are found using industry and professional organization searches (see Table 3). These resources provided insightful information about market trends, standards and software solutions already available in the market.

Table 3: Additional Literature Resources

Standards Organizations	Software/Hardware Companies
• IEEE http://www.ieee.org/portal/site • W3C (Mobile Web Initiative) http://www.w3.org/Mobile/ • Open Mobile Alliance http://www.openmobilealliance.org/ • W3C (Authoring Techniques for Device Independence) http://www.w3.org/TR/di-atdi/	• VTT Information Technology http://www.vt.fi/tte/projects/kontti • Source Forge – HTML Tidy http://sourceforge.net/projects/jtidy • Nokia http://www.nokia.com • Sun Microsystems http://www.sun.com

Writing Plan

In order to address the three main themes of the literature review topic represented in Table 1: Thematic Outline, the search strategy is framed by three key questions. The three main themes are represented in the larger question of the study: How can businesses adapt existing information assets, use middleware to assist in the delivery of content, and leverage existing investments in content management?

Table 1: Thematic Outline

Theme 1. Adaptation of Content

- Dynamic Transformation
- Explicit Transformation
- Managing Device Lists

Theme 2. The Role of Middleware

- Architecture design patterns
- Handling Content Formats

Theme 3. Leveraging Investments in Content Management

- Content Reuse
- Delivery Protocols
- Page Segmentation

Search Strategy Report

The first main theme, adaptation of content, asks: what strategies and solutions exist to adapt content for mobile and wireless devices? Literature selected to address this question examines topics including: (1) methods for transforming and adapting content to specific devices; (2) methods for automated conversion or dynamic transformation and the pros and cons of the approach; (3) methods for static or explicit transformation. The second main theme, the role of middleware, considers the role of middleware in mobile content delivery. Resources selected addressing middleware examine architecture designs and solutions that use middleware components and the roles these components play in the adaptation of information for mobile devices. The third main theme, leveraging investments in content management, raises the

question: how can businesses leverage existing investments in content management to deliver the content? Literature selected to address this question examines topics including: the delivery to client devices using protocols like WAP or i-mode; and formatting approaches such as page segmentation techniques (pulling content segments from larger pages).

Frolick and Chen (2004) believe there are different opportunities for m-commerce and m-business depending on the integration and ability to deliver usable information. Literature addressing a selected set of these different opportunities and abilities are presented in terms of the major themes in Table 1: Thematic Outline. Thematic reviews of literature are organized around a topic or issue, rather than the progression of time (The Writing Center, University of North Carolina at Chapel Hill, 2007). The research here is presented using a thematic approach and also considers the progression of time within the context of the major themes to present a more authentic approach to the review as suggested by The Writing Center, University of North Carolina at Chapel Hill (2007). The progression of time is specifically relevant to advances in technology where solutions have evolved over time.

Writing Plan Outline

Theme 1: What are the problems associated with delivering content and their current state and the necessity of content adaptation?

1. The strategies for addressing the limitations of mobile devices and content delivery
    1.1. Dynamic strategies for adapting content
        1.1.1. The dynamic paradigm for adopting content transformation to delivery mobile content

1.1.2. Required components of dynamic content transformation

1.1.3. The benefit of dynamic content adaptation/transformation

1.1.4. Using standards to address limitations of dynamic adaptation

1.2. Explicit content transformation and adaptation

1.2.1. Design of explicit content transformation systems

1.2.2. The benefit of explicit transformation

1.2.3. The cost of maintaining explicit sets of transformed content for specific devices

1.3. Managing the different devices which content is delivered to

1.3.1. Where and when maintaining a device list is required

1.3.2. The value of having a device list and the device properties

1.3.3. Combining standards with device lists and device profiles

Theme 2: The role middleware plays in the design of mobile content systems and content delivery strategies

1.4. Summary of literature on architecture and design patterns in middleware for mobile platforms

1.4.1. The role of middleware in mobile architectures

1.4.2. Uses for middleware components

1.4.3. The different types of middleware

1.5. Literature and examples for handling content formats for devices and how middleware succeeds

1.5.1. Device specific formats and how they are managed

1.5.2. Format standards for mobile devices

1.5.3. Summary of middleware and the application to formatting content

Theme 3: How middleware facilitates the leveraging of investments in content management.

1.6. Summary of literature addressing content reuse

1.6.1. How to reformat existing content and why it is important to businesses

1.6.2. Standards for delivery of content and the technologies which support them

1.6.3. The definition of page segmentation and why it is used

1.6.4. A description of how to leverage existing content for device limitations

Review of the Literature Bibliography

The resources in this bibliography are grouped into the three main themes presented in the Table 1: Thematic Outline. These thirty references represent a focused selection of the literature available on the topic of content adaptation, the role of middleware and how to use them to leverage existing investments in content management. The limitations section details the reasons for including and excluding certain topics and related materials. An abstract is included for each reference, based on the published abstract in the original source.

Adaptation of Content

The concept of 'content adaptation' refers to using software to re-authorize a web page through a series of transformations so that the page can be effectively displayed on a device and the user can interactively navigate the page (Zang, 2007). The eleven resources in this theme area are related to the adaptation of content and the approaches which have been designed to facilitate managing content adaptation in mobile information systems. The resources include overviews of the function and importance of adapting content.

De Virgilio, R., Torlone, R. & Houben, G. (2006). A Rule-based Approach to Content Delivery Adaptation in Web Information Systems. *mdm*, 7th International Conference on Mobile Data Management. 21.

Abstract: In this paper, we present a rule-based approach supporting the automatic adaptation in Web Information Systems. The approach relies on the general notions of profile and configuration. Special rules are used to specify, in a declarative way, how to build a configuration that satisfies the requirements of adaptation for a profile. The rule

evaluation technique guarantees that different contexts and orthogonal requirements of adaptation, possibly not fixed in advance, can be taken into account in the adaptation process.

Zhang, Dongsong (2007, February). Web Content Adaptation for Mobile Handheld Devices. *Communications of the ACM*. 50(2).

We have witnessed the explosive growth of mobile handheld devices such as cell phones and personal digital assistants (PDAs) in recent years. Many wireless applications have been developed for those devices, including daily news update, classified advertising, tourist guide, wireless Web portals, and m-commerce applications. The ability to communicate from virtually anywhere and the convergence of Web and wireless technologies offer an unprecedented level of flexibility and convenience, particularly for ubiquitous information access through mobile devices. However, the unique features of wireless networks (for example, low bandwidth and unreliability) and mobile devices (for example, small screen size, and low memory and processing capability), as well as the mobility of users, present challenges for taking advantage of the convenience of mobile devices for information access.

Gaedke, M., Beigl, M., Gellersen, H. & Segor, C. (1998). Web Content Delivery to Heterogeneous Platforms. *217 Lecture Notes in Computer Science (LNCS), Springer Verlag, 1552*.

Abstract. It is widely acknowledged that information such as web content should be adapted for mobile platforms to account for restrictions in mobile environments. As emerging mobile platforms such as different kinds of Personal Digital Assistant (PDA) tend to vary largely in their capabilities, we suggest that adaptation should be platform-specific. Common approaches for content adaptation are automated conversion and explicit specification of adapted content, with a trade-off between quality and development/maintenance effort. As alternative avoiding this trade-off, we propose a simple object oriented framework for content adaptation. To facilitate the use of this framework in the Web, we base our approach on the object-oriented Web Composition model and its XML-based implementation WCML. We apply our object-oriented approach to an example application to demonstrate how object-oriented specification of platform-adapted content reduces development/maintenance effort.

Hinz, M., Fiala, Z., & Wehner, F. (2004). Personalization-Based Optimization of Web Interfaces for Mobile Devices. *Lecture Notes in Computer Science,* 204-215.

Abstract: Developing personalized applications for the ubiquitous Web assumes to provide different user interfaces addressing heterogeneous capabilities of device classes.

Major problems are the lack of sufficient presentation space and the diversity of interaction techniques, both requiring adaptive intelligent user interfaces. To meet this challenge this paper introduces an approach for the personalization-based optimization of Web interfaces for mobile devices. On the basis of a user model different adaptation issues are discussed. Firstly, static adaptation mechanisms affecting the structure of Web documents as well as layout managers enabling a device independent definition of Web presentations for heterogeneous devices are introduced. Then an interactive mechanism for dynamically predicting user preferences for hiding unnecessary information through content adaptation is presented. As a proof of concept an architecture realized by a pipeline-based document generator was developed for static/dynamic adaptation, which is partly explained in this paper.

Lee, L. (2003, December). Customizing WAP-based information services on mobile networks. *Personal and Ubiquitous Computing, 7(6)*.

Abstract: In addition to voice transmission over mobile networks, the demand of data communication has been increasing. To deploy data-oriented applications for mobile terminals, the wireless application protocol (WAP) has provided a promising solution. However, as in the World Wide Web (WWW), the increasing information leads to the problem of information overload. One way to overcome such a problem is to build intelligent recommender systems to provide customized information services. By analyzing the information collected from the user, a customized recommender system is able to reason his personal preferences and to build a model of predictions. In this way,

only the information predicted as user-interested can reach the end user. This paper presents a multi-agent framework in which a decision tree-based approach is employed to learn a user's unique preferences. To assess the proposed framework, a mobile phone simulator is used to represent a mobile environment and a series of experiments are conducted. The experimental studies have concentrated on how to recommend appropriate information to the individual user, and on how the system can adapt to a users most recent preferences. The results and analysis show that based on our framework the WAP-based customized information services can be successfully performed.

Wagner, M., Kiebling, W., & Balke, W. (2002). Progressive content delivery for mobile e-services. *Augsburg: Inst. Futur Informatik*.

Abstract: In this paper we present a framework for the progressive delivery of Web documents in mobile Internet services. Progressive delivery enables users to get fast access to the most relevant parts of a document. Given the reduced bandwidth and the high costs of mobile communication the idea of progressive delivery offers a promising improvement especially for mobile e-services. The central part of the delivery consists of innovative concepts for content selection to determine the most relevant document parts for successive delivery maintaining the documents' readability. To make this selection as flexible and effective as possible we consider the user's notion of relevance together with semantic author annotations and structural document characteristics. Using XML technology documents are automatically adapted to both personal user profiles and device constraints. A prototypical mobile news service exemplifies our approach to

content selection, but our framework promises to be applicable to a broad range of future Internet services.

The Role of Middleware

The term middleware in this document refers to a set of services placed between the applications and the operating systems (Grigoras, 2006). The purpose for middleware is to identify devices and adapt content for those devices. Middleware has many applications in technology and architecture designs. The ten selected resources collected in this section highlight the role of middleware in mobile applications and content delivery.

Chakravorty, R. (2005, February). Optimizing Web Delivery Over Wireless Links: Design, Implementation, and Experiences. *IEEE Journal on Selected Areas in Communications, 23(2*).

Abstract: World over wide-area wireless Global System for Mobile Communication (GSM) networks have been upgraded to support the general packet radio service (GPRS). GPRS brings "always-on" wireless data connectivity at bandwidths comparable to that of conventional fixed-line telephone modems. Unfortunately many users have found the reality to be rather different, experiencing very disappointing performance when, for example, browsing the Web over GPRS.

In this paper, we show what causes the web and its underlying transport protocol TCP to underperform in a GPRS wide-area wireless environment. We examine why certain

GPRS network characteristics interact badly with TCP to yield problems such as: link underutilization for short-lived flows, excess queueing for long-lived flows, ACK compression, poor loss recovery, and gross unfairness between competing flows. We also show that many Web browsers tend to be overly aggressive, and by opening too many simultaneous TCP connections can aggravate matters.

We present the design and implementation of a web optimizing proxy system called GPRS Web that mitigates many of the GPRS link-related performance problems with a simple software update to a mobile device. The update is a link-aware middleware (a local "client proxy") that sits in the mobile device, and communicates with a "server proxy" located at the other end of the wireless link, close to the wired-wireless border. The dual-proxy architecture collectively implements a number of key enhancements-an aggressive caching scheme that employs content-based hash keying to improve hit rates for dynamic content, a preemptive push of Web page support resources to mobile clients, resource adaptation to suit client capabilities, delta encoded data transfer of modified pages, DNS lookup migration, and a UDP-based reliable transport protocol that is specifically optimized for use over GPRS. We show that these enhancements results in significant improvement in web performance over GPRS links.

Flores-Cortés, C., Blair, G., & Grace, P. (2007, July). An Adaptive Middleware to Overcome Service Discovery Heterogeneity in Mobile Ad Hoc Environments. *IEEE Distributed Systems Online*, *8(7*).

Abstract: Numerous protocols have emerged for service discovery in mobile ad hoc environments, and they differ significantly in terms of service description languages, interaction patterns, message type and structure, directory architectures, and so on. So, middleware is required to support the discovery of services advertised on multiple platforms and achieve interoperability between heterogeneous discovery protocols. This article presents a component framework approach for developing a configurable and dynamically reconfigurable multi-personality discovery middleware.

Frolick, M. & Chen, L. (2004). Assessing M-Commerce Opportunities. *Information Systems Management. 21(2),* 53-61.

Abstract: Shortly after the advent of digital mobile phone service, a new innovative way of doing business known as mobile commerce (M-commerce) was created. This article helps organizations gain insight as to whether mobile commerce is a business solution worth exploring. It reviews the technology behind M-commerce and the products and services currently available. It also examines the benefits and challenges of M-commerce, as well as the issues to be addressed when considering implementation of M-commerce solutions.

Haneef, A. (2004). ANMoLe—An Adaptive Multimedia Content Delivery Middleware Architecture for Heterogeneous Mobile Multi-Device Neighborhoods. *Multimedia Tools and Applications. 22*, 171–186.

Abstract. Despite the commercial onslaught of multipurpose portable devices such as integrated mobile phone-PDA combos, the need for multiple devices, with each device performing its own pre-defined and specialized function still exists today. The new generation of internet users has been expeditious in imbibing the new generation of divergent devices for their varying needs—cell phones for voice communication, pagers for text messaging and PDAs for notes. Content sources today assume that the end-device used to retrieve the content has certain minimum pre-defined capabilities. The architecture presented in this paper explores a new realm of content delivery where all the devices in a user's neighborhood of devices are united as a single entity for content delivery. This solution exploits the characteristic capabilities of these individual devices to render the retrieved content for the user; or in cases where the target devices are limited in capabilities, modifies the content to suite the capabilities of the device. A comprehensive description of the test bed we have built based on this architecture is also described.

Lawson, S. (2006). Mobile Middleware Push. *Tech Watch*: 2006.

Abstract: Mobile Middleware for messaging and management garnered the lion's share of attention from vendors at the Cellular Telecommunications & Internet Association (CTIA) Wireless IT & Entertainment 2004 conference in San Francisco last week. The article discusses the market penetration of mobile middleware pushes and the companies executing on them.

Minhee Chae, M. & Jinwoo, K. (2004, May). Do size and structure matter to mobile users? An empirical study of the effects of screen size, information structure, and task complexity on user activities with standard web phones. *Behavior & Information Technology*, 23(3), 165-181.

Abstract: The small screens of mobile Internet devices, combined with the increasing complexity of mobile tasks, create a serious obstacle to usability in the mobile Internet. One way to circumvent the obstacle is to organize an information structure with efficient depth/breadth trade-offs. A controlled lab experiment was conducted to investigate how screen size and information structure affect user behaviors and perceptions. The moderating effects of task complexity on the relationship between screen size/information structure and user navigation/perceptions were also investigated. Study results indicate that both information structure and screen size significantly affect the navigation behavior and perceptions of mobile Internet users. Task complexity was also

found to heighten the influence of information structure on user behaviour and perceptions. The paper ends with a discussion of theoretical and practical implications, among them a key implication for mobile Internet businesses: for corporate intranet systems as well as m-commerce transaction systems, the horizontal depth of information structures should be adapted to task complexity and anticipated screen size.

Vaughan-Nichols, S. (2004, May). Wireless Middleware: Glue for the Mobile Infrastructure. *Computer*.

Abstract: Article discusses the role of middleware in the mobile market place and the different technologies which effect how the middleware is integrated into the systems it supports.

Leveraging Investments in Content Management

Content may be thought of as information and experiences created by individuals, institutions and technology to benefit audiences in contexts that they value (Wikipedia, “Content”, 2007). Considering this definition, middleware architecture creates a transparent layer between the content and the device that allows continual reuse of the content management assets (Guo, 2006). These ten references on middleware and the application of middleware to existing content management systems are included because they relate to the adaptation of content to leverage existing investments in content and content management.

Abbass, I. (2006, January). Jump on the Mobile Delivery Bandwagon. *Television Week. 25(3)*, 9-9.

Abstract: The article discusses the use of mobile devices as direct marketing tools for content owners and brands. Short message service or text messaging is the most common and easiest method of exploiting mobile devices. There are three application types that allow content owner to create and maintain a relationship via their mobile devices. In each of the applications, integration with other marketing efforts and media is key to an effective marketing strategy.

Assad, A. and Souto, N. (2007, August). Device Middleware for Mobile Applications. *IEEE Distributed Systems Online*, 8(8).

Abstract: D-Mid (Device Middleware) supports mobile applications built on different programming languages but running on the same device, so the applications can communicate.

Frolick, M. and Chen, L. (2004). Assessing M-Commerce Opportunities. *Information Systems Management.* 21(2), 53-61.

Abstract: Shortly after the advent of digital mobile phone service, a new innovative way of doing business known as mobile commerce (M-commerce) was created. This article helps organizations gain insight as to whether mobile commerce is a business solution

worth exploring. It reviews the technology behind M-commerce and the products and services currently available. It also examines the benefits and challenges of M-commerce, as well as the issues to be addressed when considering implementation of M-commerce solutions.

Grigoras, D. (2006). Challenges to the Design of Mobile Middleware Systems. *Parelec*. International Symposium on Parallel Computing in Electrical Engineering. 14-19.

Abstract: Mobile networks provide mobile users with access to computing services and resources anywhere, anytime. While each mobile device has limited resources and services, all of them, by networking, can create a powerful computing mobile platform. The role of the mobile middleware is to facilitate this platform. This paper discusses the main features of mobile networks that represent challenges to the design of a cost-effective mobile middleware layer, then presents several ongoing middleware projects and, in the end, focuses on an original solution.

Guo, P. (2007). Architectural style based modeling and simulation of middleware for mobile systems. *Univ., Diss.,*Paderborn. Retrived December 15, 2008, from http://ubdata.uni-paderborn.de/ediss/17/2007/guo/disserta.pdf

Abstract: We develop the approach based on UML-like meta modeling and graph transformation techniques to support sound methodological principles, powerful modeling, formal analysis and refinement. The approach consists of several main parts: the modeling language that supports specification of the style and mobility, the refinement formalization that ensures that an abstract style is correctly refined to a

concrete one, as well as the consistency check framework that validates behavioral consistency between two styles on different abstract layers. With the Fujaba simulation tool support, we also develop a style-based engineering process that helps us to efficiently develop correct and consistent styles. Besides, it allows a seamless integration of our approach into the well-known object oriented design. By providing a concrete example of how to construct the style for a class of related middleware, and how to use the style to help the design and development of a new middleware, we show that the architectural style-based approach is useful and practical.

Hua, Z. (2006, December). Design and Performance Studies of an Adaptive Scheme for Serving Dynamic Web Content in a Mobile Computing Environment. *IEEE Transactions on Mobile Computing. 5(12)*.

Abstract: Currently, people gain easy access to an increasingly diverse range of mobile devices such as personal digital assistants (PDAs), smart phones, and handheld computers. As dynamic content has become dominant on the fast-growing World Wide Web [24], it is necessary to provide effective ways for the users to access such prevalent Web content in a mobile computing environment. During a course of browsing dynamic content on mobile devices, the requested content is first dynamically generated by remote Web server, then transmitted over a wireless network, and, finally, adapted for display on small screens. This leads to considerable latency and processing load on mobile devices. By integrating a novel Web content adaptation algorithm and an enhanced caching strategy, we propose an adaptive scheme called MobiDNA for serving dynamic content

in a mobile computing environment. To validate the feasibility and effectiveness of the proposed MobiDNA system, we construct an experimental test bed to investigate its performance. Experimental results demonstrate that this scheme can effectively improve mobile dynamic content browsing, by improving Web content readability on small displays, decreasing mobile browsing latency, and reducing wireless bandwidth consumption.

Salz, P. (2006, June). *Mobile Delivery Discoveries*. EContent. 29(5), 44.

Abstract: The article discusses developments related to mobile search and content discovery. A new breed of software that effectively automates and personalizes the delivery and display of mobile content directly on the user's device has been developed. The solution enables content owners and brands to deliver branded portal content on mobile phones through a client application. Through the software, users gain a 24/7 access to the content as well as updates, promotions or special offers. This software leverages the handset's capabilities to deliver a more appealing user experience, increase service awareness and streamline purchasing.

Review of the Literature

Middleware has an important role in connecting distributed mobile systems. The twenty selected references reviewed here focus on three areas: (1) mobile architecture strategies, (2) the role of middleware, and (3) the ability to leverage existing investments in content management for delivering content. All of the references are written in the context of delivering content to mobile devices. Focus on these three areas is important because many of the referenced articles also provide detailed solutions and research that is specific to technical problems outside the scope of this review. The common thread through all the selected works is a use of middleware and adaptation of content as a primary component. The following review summarizes and consolidates information collected from these references concerning the use of middleware to deliver and transform mobile content and the benefits thereof.

Area 1 - Mobile Architecture Strategies

Hinz et al., (2004) outline two central concepts of delivering content to mobile devices. They cover both the "dynamic" and "static" methods for content adaption and their pros and cons. In their paper titled "Personalization-Based Optimization of Web Interfaces for Mobile Devices", Hinz et al., (2004) describe a dynamic approach that adapts existing web pages designed for traditional PC web browsers to the different device capabilities and limitations by adjusting the format of the pages. This type of dynamic adaptation is suited for adapting arbitrary web pages. Because of the limitless number of page designs and content structures Hinz et al., feel it is impossible to predict the results of every adaptation and the results often include unnecessary

page elements and information. Even though there are limitations to the dynamic approach it is the primary focus of this work.

Dynamic adaptation.

Wagner et al. (2002), propose three layers of dynamic adaptation for the delivery of different formats of content. The exact terms Wagner et al. (2002) uses are media synthesis, format optimization and content selection. These three functions of middleware can be more generically described as the technical layers which content goes through during a dynamic transformation. To adapt content dynamically and reliably for different devices requires a series of components and functions to be performed by the middleware. Any content pages can be processed dynamically and the information pushed into a format for mobile device with different degrees of success. Gaedke et al., and Hinz et al., both suggest that to perform effective dynamic adaptations a document model or object oriented framework for adaptation is necessary.

In their research Hinz et al. agree with Gaedke et al. that the main benefit of the dynamic approach is the reduction in effort required to adapt any content for a mobile device. Dynamic adaptation is advantageous for content and application developers because of the limited amount of additional effort required to adapt large volumes of content for mobile devices (Gaedke et al., 1998). The most acceptable results are obtained from systems which include some way to classify the elements of the content pages and provide a predictable document structure for middleware to interpret when performing adaptations (Gaedke et al., 1998). Even with the limitations and issues predicting the results of dynamic adaptation the low amount of effort

required to begin delivering mobile content make the dynamic method an attractive alternative to the more costly explicit approach.

Hinz et al. (2004) suggest that limitations exist with the dynamic adaptation of general web content. The lack of predictable page designs and standard markup that content is published in make many dynamic page transformations result in unusable page formats. More implicit use of standards for the development of new content and the classification of elements in the existing content pages can address the limitations of dynamic adaptation (De Virgilio, 2006). A document model is the hierarchy of a content page which describes the different regions such as header, navigation, title, body and footer. The recommendation in Hinz et al.'s work is to standardize the document model into layers which help the middleware applications make decisions when dynamically adapting content for specific device profiles. With a standard document model for content the dynamic adaptation process can become more intelligent and conditional variations can be proposed for different devices and displays. For example, a monochrome display has only one color it renders information using one of the most limiting profiles available in mobile devices. If the body of a content page is categorized using a standard document model, the different elements can be adjusted for monochrome displays without color and be processed with a different adaptation when requested by a device with a color display (Hinz et al., 2004).

Explicit transformation.

The alternative method to dynamic adaptation is explicit adaptation. Explicit adaption is planned from the ground up knowing the content will need to be accessed by different devices, running different applications and browsers with different limitations (Hinz et al., 2004). Explicit

adaptation systems have three main components and can include more depending on the additional features required. Gaedke et al. presents the details of three main components: (1) an XML based composition or description that classifies the different page elements similar to the document model, (2) the middleware logic which interprets the XML descriptions (3) and a device list which maintains the device type with the limitations and features of the device. The device list is reference by the middleware logic when the pages are requested and the logic is used to adapt explicitly defined page.

Explosive growth of the mobile internet requires that dynamic adaption be used to provide continuous access to information created and managed by systems which were developed prior to the increase in mobile devices. Dynamic adaptation gives users access to any information but the transformations are not predictable (De Virgilio et al., 2006). The most predictable way to deliver content in different formats for different devices is using an explicit transformation (Hinz et al., 2004). Explicit transformations are built from the ground up for different devices (Hinz et al., 2004).

De Virgilio et al., (2006) in their research demonstrate a process of adaptation based on the notions of profiles and configurations, and on a notion of matching between profiles and configurations. A device list is required so that matching configurations and profiles can predictably adapt content to the attributes and limitations of device. Systems use the term "profile" in the context of the features and attributes of a mobile device. It is valuable to maintain a list of the intended devices and device properties to execute dynamic adaptation schemes

against so that middleware logic can be mapped to meet specific features and attributes maintain in the device list profiles (De Virgilio et al., 2006).

It is convenient to access information using mobile devices, but the overwhelming amount of information contained in a single web page needs to be overcome to make reading the page effective on the limited displays of mobile devices (Lee & Lu, 2003). Wagner et al.'s (2002) proposed layers of dynamic adaptation allow the information in any format to be transformed into a standard format supported by a specific device profile. Middleware takes advantage of mobile format standards such as WML and WAP as stable and predictable content formats that mobile devices can use reliably (Gaedke et al., 1998). Lee and Lu (2003) in their paper on Customizing WAP-based Information Services present a strategy and the benefits of combining standards, device lists and profile information. To overcome the device limitations Lee and Lu (2003) propose leveraging WAP and WML, and constructing a document model to classify the page elements for adaptation. To further support delivering the page element that each user wants Lee and Lu (2003) use an information agent to collect user preferences and priorities for the different page components. The information agent allows the user to provide a set of preferences and priorities for how the different regions of the document model are handled by the middleware transforming the content (Lee and Lu, 2003).

Area 2 - The Role of Middleware

Middleware is a software layer that resides between programs, OSs, hardware platforms, and communications protocols (Vaughan-Nichols, 2004). There are a growing number of applications, protocols, operating systems, processors, and architectures available today

(Vaughan-Nichols, 2004). These include WiFi (IEEE 802.11) wireless LAN technology; code-division and time-division multiple access wireless-communication protocols; various types of PDAs, smart phones, and laptops; and architectures based on numerous processors (Vaughan-Nichols, 2004). Middleware lets devices communicate across the growing number of applications, service and protocol without intervention from the users. Middleware allows future and legacy application content and data sources to be available to the mobile internet.

Mobile architectures.

Middleware is a broker between mobile devices and content (Hua et al., 2006). As a broker, the middleware understands if a device is requesting content, what device is requesting the content and the middleware can make decisions and apply adaptation logic to the content (Hua et al., 2006). The adaptation logic can be based on the content or can be a combination of adapting the format and information in the content as well as the methods or protocols the content is delivered over (Hua et al., 2006). Middleware layers in mobile architectures are combinations of adaption logic and delivery mechanisms to best deliver content to mobile devices (Grigoras, 2006). The specific purpose of having middleware available in an architecture is to address the known limitation of device displays and the overall user experience of browsing the over whelming amount of information on a traditional web page (Grigoras, 2006).

Middleware is not just connecting devices and technologies but also is connecting companies from different niche markets (Vaughan-Nichols, 2004). Along with adapting content and connecting devices middleware is also creating a new market place for technology companies (Vaughan-Nichols, 2004). Traditional content hosting companies, hardware providers and

communications companies are using middleware to deliver content and applications to new demographics and users which were difficult to reach until the growth of the mobile internet (Vaughan-Nichols, 2004). This new connection between business partners is opening the door for new alliances between companies who previously did not interact as business partners (Vaughan-Nichols, 2004). Middleware is a collection of functions and features the hardware serving the content does not natively support but that are required to best deliver the hosted content to mobile devices (Grigoras, 2006). The following list of uses for middleware (see Table 1) is suggested by Grigoras in "Challenges to the Design of Mobile Middleware Systems" (2006).

Table 4: Middleware Uses and Benefits

Middleware Use	**Middleware Benefits**
Transparency	Enables seamless access to services and resources across multiple applications, irrespective of the device providing them.
Cost-effectiveness	Uses standard or common procedures and protocols that lower costs by enabling integration.
Simplicity	Simplifies access and execution of methods and actions between applications. Middleware flexibility simplifies architecture designs and solutions.
Scalability	Extends the number and capabilities of connected applications, allowing independent growth of application tiers.
Portability	Enables services and applications to be moved between different environments by removing communication responsibilities from the applications to the middleware.
Adaptability	Enables protocols and applications to be adapted to the characteristics of the mobile device.
Dynamic reconfiguration	By configuring applications to communicate through middleware, middleware applications can dynamically reconfigure themselves to adapt when the topology changes.
Asynchronous interaction	Interaction can be timed and planned depending on the requirements of each request, this is important as a result of mobility and the changing environments of mobile devices.

Middleware Use	**Middleware Benefits**
Quality of service	Adapts to provide the best QoS supported by the available communication protocols.
Fault-tolerance and recovery	Allows connections between devices and applications to be passed between parallel environments, very important in the mobile context to maintain connectivity and QoS.
Security	Creates layers of security for both communication and remote execution between applications and servers.

Grigoras (2006) presents the functions of middleware as the actions which middleware can perform to address the limitations of mobile devices and mobile networks. These functions are grouped in different combinations to create different types of middleware serving different needs of mobile internet users. Information and technical manager should review and consider the information in *Table 4: Middleware uses and Benefits* while evaluating solutions. The uses in Table 4 are the concepts that make up the "Glue" Guo (2006) have labeled middleware as.

When considering the role of middleware in mobile systems content, adaptation is a major function. But it is also important for information managers to consider the additional influence middleware has on m-commerce systems. M-commerce is not just about content; it includes transactions between the mobile devices and commerce systems (Frolick & Chen, 2004). M-commerce systems take advantage of middleware to adapt the application pages for device limitations and also provide transactional enhancements, caching features and transformation of transactional messages to desperate commerce systems (Frolick & Chen, 2004). In m-commerce systems, middleware creates application transparency by connecting applications in a seamless way to respond to users' request.

Managing Device Profiles and Standards

Guo (2006) presents the most complete paper provided in this review to understand the role of middleware, the services middleware can provide and how to develop and simulate a middleware layer in the development of mobile systems. Middleware is sometimes called a glue technology because it connects distributed components of a system making them interoperable (Guo, 2006). Middleware designs include a list of devices and system components to be managed independently of the middleware programs. One way to store devices and their properties is by using a device profile registry (Haneef & Ganz, 2004). When considering the information in Table 4 managers should understand that the device registry is a common component that middleware relies on but it is not a use for middleware. This registry allows the device profiles to be abstracted form the applications adapting content (Haneef & Ganz, 2004). This separation allows the devices and the features to be requested on demand and the middleware program can respond with formatted messages which the devices understands (Guo, 2006). This allows once disparate devices to communicate in standard and predictable ways (Guo, 2006).

Format standards for mobile device displays include WAP, XML and WML, but the format standards are not limited to the display of content. Format standards are important for middleware to enforce when communicating between applications users request information from (Guo, 2006). Middleware allows multiple applications to interact and provide responses to requests as a single standard message (Guo, 2006). In Table 4, Grigoras (2006) presents transparency among applications as a major use for middleware. The middleware leveraging standard communication protocols and message formats are what make application transparency possible (Guo, 2006).

Middleware to leverage investments in content management.

Middleware allows applications to avoid being locked into proprietary vendor products and formats making content and features reusable for mobile devices (Vaughan-Nichols, 2004). Grigoras (2006) includes "Cost Effectivness" as a use for middleware in Table 4. This association is accurate but is better stated as a reason to use middleware rather than a use for middleware. Because applications using middleware are freed from proprietary vendor products, mobile devices can access multiple applications and data sources (Vaughan-Nichols, 2004). Middleware allows vendors to move applications in a more agile way between hardware without extensive rewriting of the application code. This allows applications to be developed at lower costs and content to be reused more efficiently adding value to the content (Vaughan-Nichols, 2004).

Kumar and Hammainen (2004) present a progressive idea for content reuse and distribution. Peer to peer or P2P is the ability to distribute and reuse content between peer clients connected to a services provider (Kumar & Hammainen, 2004). The more common way of reusing content by introducing middleware to adaptation is further enhanced when the content is reused for different applications between peers (Kumar & Hammainen, 2004), thus providing a low cost approach for businesses to reuse content and distribute it. It is important for technology managers to understand the value proposition of P2P for content distribution when combined with traditional middleware for content adaptation.

Abbass (2006) describes the different strategies that companies can take to get into the mobile content market. A Short Messaging Service (SMS) campaign which reuses existing marketing content is one approach to directly contacting a specific list of users (Abbass, 2006). Companies can also adapt an existing web site to the Wireless Application Protocol (WAP) which requires middleware and users to enter a URL into their mobile device and navigate and download pages (Abbass, 2006). A third approach is to add the content to an umbrella brand (i.e., a brand that covers diverse kinds of products which are more or less related) that delivers content through a central middleware system to subscribers of a specific network such as Verizon's VCast (Abbass, 2006). A fourth approach for companies that have the resources is to create a custom branded portal to deliver content to users (Abbass, 2006). This is the most resource intensive approach and requires an organization that is mature enough technically to manage it (Abbass, 2006). Each approach has positive and negative points and information managers need to consider them carefully in light of their own situation and needs when choosing a strategy to enter the mobile content market.

Standards and technologies for mobile content delivery.

Salz (2006) presents a specific example of client based middleware that is available on the content requestor's mobile device. The client based middleware model has the benefit of understanding the capabilities and limitations of the device the software is installed on (Salz, 2006). Client middleware lives on the mobile device as opposed to middleware that is installed on servers and accessed by mobile devices (Salz, 2006). The client middleware can be configured to adapt content to device limitations and also deliver personalized content based on

the users' preferences (Salz, 2006). Businesses can reuse digital files of branded communications and entertainment content from different formats and applications, and rely on the client middleware application to optimize the user experience (Salz, 2006). Additionally the software based middleware can be updated remotely when new formats or devices features become available with almost no user intervention (Salz, 2006). The ability to produce content once and reuse it many times is the way businesses get the most out of investments in content development and reuse.

To evangelize standards for content distribution between devices and applications, Assad and Rosa (2007) present a use case example of an open source middleware that can adapt content for communication between applications. Content is considered in this paper to also include information exchanged between systems. Assad and Rosa (2007) created D-Mid (Device Middleware) to support mobile applications built on different programming languages but running on the same device. This approach bridges gaps between applications which are built without consideration for format and protocol standards for exchanging information (Assad & Rosa, 2007).

The definition of page segmentation and why it is used.

Page segmentation is the process of partitioning large web pages into a series of tailored content blocks (Hua et al., 2006). Page segmentation is accomplished with a dynamic process that relies on an algorithm to interpret the priority of content on a page and the best way to present the content to a mobile device (Hua et al., 2006). Page segmentation is important to adapting content in a way that optimizes performance and user experience (Hua et al., 2006). Hua et al., (2006) present page segmentation as an approach that takes normal adaptation of content to the next

level. They predict that the next generation of content transformation algorithms will consider how to adjust the content for page displays in ways which address device limitations and segment the pages into chunks which are intuitive to read on the specific devices enhancing the overall user experience (Hua et al., 2006).

Haneef and Ganz, (2004) present a use case for building a middleware framework to address device limitations and reuse existing content that includes page segmentation. Haneef and Ganz call their framework Application-level Networking solutions for Mobile users (ANMoLe). The goal of this framework is to empower the network infrastructure to enable multi-device, multi-modal communication for mobile users (Haneef & Ganz, 2004). The components of ANMoLe which are of particular interest to technical and information managers are outline in Table 5: ANMoLe Components and Uses (Haneef & Ganz, 2004).

Table 5: ANMoLe Components and Uses

Component	Use
Rule-based Content Processor Engine	The Content Processor takes the compiled IRML rules as defined by the user and performs actions on the message entities. The actions taken may include invocation of web services to act on the message entity.
Web Service Client Interface	This interface functions between the Content Processor Engine and Web Services available on the Internet. This allows for a generic interface to various web services, allowing the components of the message entities to be transformed, if needed, by web service components.
Device (Profile)	The Device Profile Parser parses the device profiles stored

Component	Use
Parser and Registry	of the devices in the user's neighborhood and stores them in the Device Profile Registry. The Device Profiles may be stored as CCPP documents. Ideally, devices should be able to register their composite capabilities automatically with the Personal Proxy. The Media Splitter module accesses this registry to identify the devices currently in the user's neighborhood that can be used for delivering the content.

Conclusions

The purpose of this literature review is to describe how content is adapted for delivery to mobile devices. The focus is on (1) mobile architecture strategies, (2) the role of middleware, and (3) the ability to leverage existing investments in content management for delivering content to mobile devices. This literature review provides an examination of the detailed role of middleware and the benefits of content reuse for mobile devices, so that technical managers can understand what is possible.

Strategies exist for designing architectures specifically for mobile content delivery. As information and technical managers build solutions for mobile content delivery they must consider the devices and content that is being delivered. These solutions will integrate the best techniques for creating new content and adapting existing content. The term architecture is not limited to strategies for servers and networking. The term architecture includes the design of information and how it is adapted (Hua et al., 2006). The architecture of information for mobile devices requires classification and tagging of page elements and content. This tagging is what gives middleware logic the ability to apply adaptation logic and page segmentation algorithms based on knowledge about the limitations of devices and device displays (Hua et al., 2006).

Information and technical managers benefit from understanding the importance being able to identify devices by their properties using a device registry, and how this information benefits middleware systems (De Virgilio, Torlone & Houben, 2006). Device registries create a powerful abstraction from the middleware logic. These solutions are extensible over time with the ability to add new device profiles and content formats to existing middleware logic (Hinz et al., 2004).

A device registry promotes transparency between applications and middleware creating a homogenous system from disparate applications. More content and features becoming available to mobile users with less effort is the result.

Mobile devices are connecting users with content on demand but the limitations of the devices and the formats that content is created in limit the usefulness and overall experience for users (Jain, Puglia, Wullert, & Bakker, 2004). Companies and solution designers recognize these issues and limitations and are designing middleware based solutions to address them (Hinz et al., 2004). Dynamic adaptation and page segmentation are two effective approaches for addressing the issues of format and display limitations (Gaedke et al., 1998). As information and technical managers gain access to more mature products that provide page segmentation algorithms and dynamic adaptation rules, more content will be available with an overall better browsing experience for users (Gaedke et al., 1998).

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Appendix A - Research Strategy Documentation

Search Engine / Database	Search Terms	Results	Quality of Results	Notes
Science Research Portal http://www.scienceresearch.com/search/	Mobile Content	45	Excellent	Additional searches will be done with this search engine but it has been not working for the last few days.
Article First	Mobile Content Delivery	10	Excellent	
	Mobile Content Middleware	9	Good	
	Mobile Content Design	5	Good	
	Content Adaptation	30	Good	
	M-Business	13	Good	
Papers First	M-Business	29	Poor	
Web of Science	Mobile Content Delivery	30	Good	

Search Engine / Database	Search Terms	Results	Quality of Results	Notes
	Mobile Content Middleware	28	Average	
	Mobile content design	30	Average	
	Content Adaptation	30	Average	
Academic Search Premier	Mobile Content Delivery	30	Good	
	Mobile Content Middleware	9	Good	
	Mobile Content Design	30	Good	
	Content Adaptation	30	Average	
WorldCat	Mobile Content Middleware	234	Average	
	M-Commerce	49	Good	
	M-Business	168	Average	
	Mobile Content	389	Good	The year 1997 returned 5 results. The year 2006

Search Engine / Database	Search Terms	Results	Quality of Results	Notes
				returned 40 results and the year 2007 returned 50 results.
OneSearch	Mobile Content Transcoding	60	Good	
LexisNexis Academic	WAP	354	Excellent	Used controlled vocabulary combined with search from the Journal section of OU: **Information Technology > Mobile Computing > General Search - Informa Telecoms Source Information > (WAP)**
Journal: IEEE Transactions on Mobile Communicaitons	Mobile Middleware	100	Excellent	The IEEE Computer Society contains the most relevant a focus literature of all the sources so far.

Search Engine / Database	Search Terms	Results	Quality of Results	Notes
	Mobile Content Delivery	100	Excellent	
	Mobile content adaptation	100	Excellent	
Google Scholar http://scholar.google.com	Content Adaptation	1,300,000	Good	The quality of results in Google scholar is good but most of the results require an account. The
Yahoo http://www.yahoo.com	Mobile Information Architecture	49,900,000	Average	The initial two pages of results showed good information about companies work in the industry and how it is being applied to business. Especially Java standards.
	Smartphone Content	13,400,000	Poor	The results were not relevant to the literature review but they did

Search Engine / Database	Search Terms	Results	Quality of Results	Notes
				contain many content providers which adapt content for mobile devices dynamically.
Sage Journals Online	Mobile Content	213,921	Poor	Huge number of results but the range of people which the journals are written about is very diverse so finding focused result on topic is difficult.
	Information Managers	229,395	Poor	
SpringerLink	Mobile Content Middleware	25	Average	
	WAP	100	Excellent	WAP searches are retuning very relevant results for references about the format of content.
	Mobile Content	150	Average	Results were mixed with

Search Engine / Database	Search Terms	Results	Quality of Results	Notes
	Reuse			many papers on the topic of reusable component in software and content delivery networks. Additional sorting was required to get the mobile content references.