



# Carrier Ethernet for Mobile Backhaul Implementation Agreement

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## 1 Abstract

This paper is geared to mobile service providers that are facing escalating demands for capacity and next generation services, and for fixed line providers who see mobile backhaul network services as a new revenue opportunity. It provides generic guidelines for Ethernet backhaul architectures for mobile networks (2G, 3G, 4G/LTE) and explains how to apply existing MEF specifications, including MEF Mobile Backhaul Implementation Agreement - Phase 1, approved in January 2009 as MEF 22.

## 2 Introduction

Up until now, mobile backhaul networks have been realized using TDM and ATM technologies. However, these networks are no longer capable of keeping pace with the bandwidth capacity and reliability requirements of increasingly popular voice, data and video broadband applications on mobile devices. To meet these demands, next generation mobile equipment and networks are migrating to Ethernet, which is optimized for packet data traffic and is becoming increasingly available at sites because of Ethernet's flexibility to be transported over a multitude of transport media (fiber, copper, microwave). According to recent forecasts by Infonetics Research<sup>1</sup>, it is projected that worldwide Ethernet (copper and fiber) backhaul will grow to nearly 543K new connections between 2007 and 2011, representing a 235% CAGR.

But why, you may ask, do I need an Ethernet based backhaul network? How is it different from other Ethernet networks? Because of several factors, including the rapid handoff between base stations in mobile networks, Ethernet backhaul circuits require very tight performance requirements that must be supported by a deterministic architecture to reduce the number of hops required in a call. To meet these reliability benchmarks, mobile backhaul networks must provide the same level of network protection as PDH or SONET/SDH based networks.

The MEF has identified specific requirements for mobile backhaul applications and has developed the Mobile Backhaul Implementation Agreement (MBIA) that advises service providers how to successfully and cost-effectively implement Carrier Ethernet for mobile backhaul. The MBIA covers four major use cases that guide the service provider in setting performance and quality of service parameters, synchronization options, recovery and protection mechanisms, and Ethernet OAM services. In addition, a Generic Inter-Working Function (GIWF) is defined for legacy (e.g. TDM) traffic to be efficiently carried over the Ethernet network.

Packet-based mobile backhaul networks introduce new architecture elements that need to be named and defined unequivocally. The MBIA has identified several elements and named them to establish a common language to ensure a consistent description of the element's backhaul network requirements. This normative naming approach is used to accelerate the adoption of Ethernet-based mobile backhaul networks across the industry.

This paper discusses what the MEF Mobile Backhaul Implementation Agreement is and why it is important to service providers planning to deploy their own Ethernet based Radio Access Networks (RAN) or lease Ethernet services for mobile backhaul.

### 3 Requirements of Ethernet-based backhaul networks

The increase in data traffic in mobile networks is growing exponentially due to high bandwidth applications and the escalating use of mobile Internet access. Legacy networks are not able to cost-effectively keep up with this demand, and they can't scale to serve the transport of broadband applications expected in the near future. Industry analysts, such as Michael Howard, principal analyst and founder of Infonetics Research, assert that Ethernet is the only solution for next generation mobile backhaul networks.

Requirements on the backhaul network are imposed by 2G/3G/4G Radio Access Networks themselves as well as the services that run on these mobile networks. Class of Service requirements aligned with 3GPP, 3GPP2 and 802.16/WiMAX based services, include prioritizing the following classes from high to low for the service being implemented:

- Conversational (voice, whether IP- or TDM/ATM-based),
- Streaming (streaming video)
- Interactive (web browsing)
- Background (non-interactive data)

Other classes may also be included for OAM, control traffic, and synchronization.

In order to ensure smooth handover of calls and overall network performance, accurate synchronization is essential. The migration to all packet networks introduces the risk of losing synchronization derived from the TDM primary reference clock (PRC).

Performance, reliability and availability requirements that may vary for voice, video and VoIP, and best effort mobile applications, services must be engineered and enforced. For example, for voice quality to be maintained, latency and jitter requirements are specified. Low packet loss rates are imposed to assure mobile video quality, and reliability is addressed with requirements for fault detection, path redundancy and restoration requirements.

Multiple generations of radio access backhaul networks must be supported, with scalable consolidation that enables backhaul of any combination of 2G/3G voice and data traffic over a single Carrier Ethernet RAN, and the ability to evolve to support 4G/LTE networks as well.

### 4 What is the Implementation Agreement and why is it important?

The Mobile Backhaul Implementation Agreement (MBIA) advises service providers how to successfully and cost-effectively implement Carrier Ethernet for Mobile Backhaul, explaining how to apply existing MEF specifications and industry standards to meet RAN backhaul requirements. It enables the deployment of profitable, data-driven mobile services, communicating both the benefits and technical implementation details. It is a guide, aiding mobile service providers as they prepare their RAN backhaul networks to meet current dynamic market and economic conditions. Key to the MBIA is preserving voice-based service revenue with a transition path that supports legacy technologies and an evolution to 3G and 4G. The MBIA includes recommendations for the network design, architecture, and operation of packet-based Mobile Backhaul networks.

The MBIA also introduces several terms for mobile backhaul architectural elements to describe the new packet-based mobile radio systems. These terms are defined in the MBIA standard to ensure a consistent naming convention across the industry. It is recommended that Service providers and equipment vendors adopt these terms to avoid confusion about what

requirements are relevant at different architectural and service levels of the packet network. Table 1 summarizes these new terms.

MBIA Element	Description
<b>GIWF</b>	Generic Inter-working Function Provides adaptation and interconnection between TDM interfaces of legacy mobile equipment in the RAN BS and RAN NC, and the existing Ethernet UNI in the Carrier Ethernet Network domain.
<b>RAN CE</b>	RAN Customer Edge A generic term that identifies a mobile network node or site, such as a RAN Network Controller (RAN NC) or a RAN Base Station (RAN BS).
<b>RAN BS</b>	RAN Base Station Either a single base station node or a collection of several base stations that perform the mobile radio transmit and receive functions in a cellular radio network architecture.
<b>RAN NC</b>	RAN Network Controller A single mobile network controller or a site composed of several mobile network controllers including OSS, UMTS Radio Network Controllers, WiMAX Access Services Gateways (ASN) or network synchronization servers.

**Table 1: Terminology of new architecture elements for mobile backhaul packet networks**

Backhaul services need to be scalable, flexible and cost-effective. Existing MEF service definitions and attributes exist, enabling the mobile service provider the ability to customize their service offerings. These port-based and VLAN based Ethernet virtual connection (EVC) services (point-to-point and multipoint) are: Ethernet Private Line (E-Line), Ethernet LAN (E-LAN), and Ethernet Private Tree (E-Tree).

Performance and availability requirements are met with Ethernet OAM, which monitors Ethernet services by verifying connectivity, identifying configuration faults, measuring service performance, and performing loop-back testing.

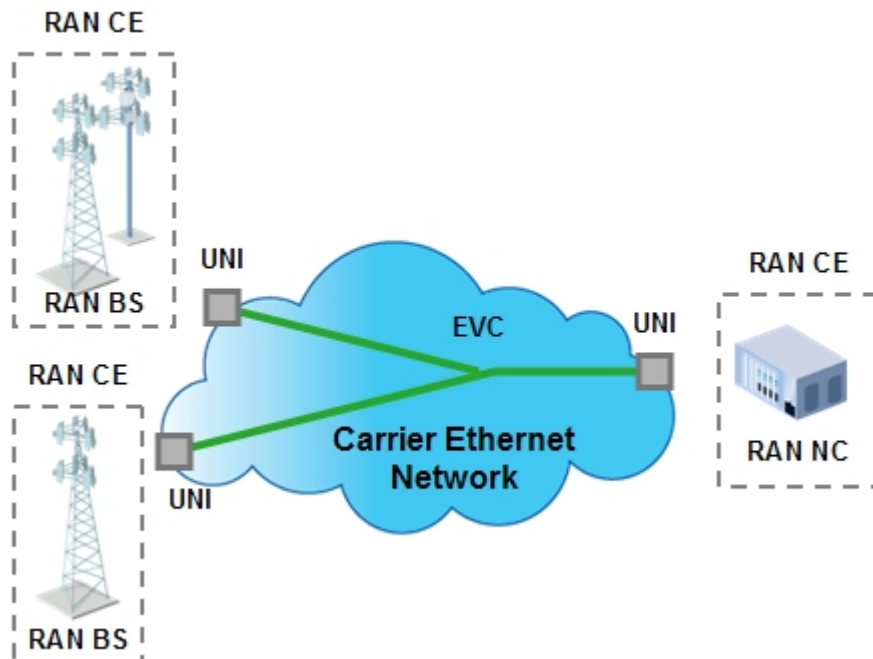
The MBIA identifies four generic deployment scenarios that differ based on the service provider's desire to separate and contain legacy voice traffic over existing networks, or the ability to maintain two networks. The use cases illustrate how the requirements are implemented.

## 5 Use Cases for RAN transport compatibility

### 5.1 Reference models

A mobile backhaul network can take on a constellation of forms depending on factors such as transport technology, mobile standards, service provider preference, etc. The MBIA focuses on the network between RAN Base Stations (RAN BS) and RAN Network Controllers (RAN NC), herein referred to as mobile backhaul radio access network. The mobile backhaul can be interchanged with the Carrier Ethernet Network (CEN) with respect to the reference model in this MBIA. Figure 1 describes a simple reference model where the mobile backhaul is a single CEN that connects the mobile network nodes, referred to as the RAN Customer Edge (RAN CE).

RAN CE is a generic term that identifies a mobile network node or site, such as a RAN NC or a RAN BS. A RAN NC may be a single network controller or a site composed of several network controllers including: OSS, WCDMA Radio Network Controller, or synchronization server. A RAN BS may also be a single base station or a collection of several base stations. Multiple RAN NCs and RAN BSs can be connected to the CEN at any given time.

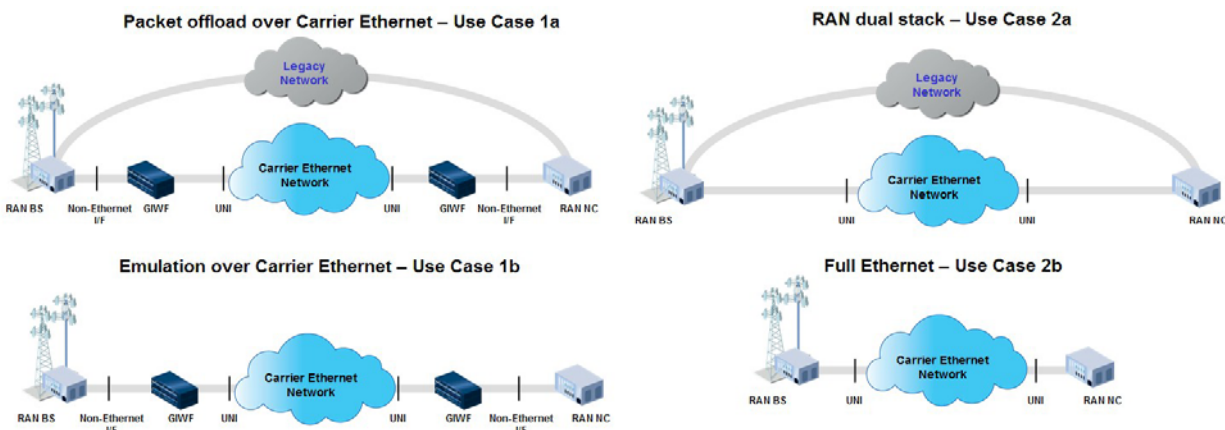


**Figure 1 : Single CEN Domain Mobile Backhaul Reference Model**

More complex scenarios involving multiple CEN domains are possible but these are out of scope for Phase 1 of the Mobile Backhaul Implementation Agreement and are left for further study.

## 5.2 Use Cases

There are many possible deployment scenarios in mobile networks backhaul segment. As illustrated in Figure 2, the Implementation Agreement identifies four generic deployment scenarios that capture the main short term and long term deployment possibilities. Basically there are two major modes. Use case 1 assumes RAN NC and RAN BS don't have native Ethernet interfaces and require an interworking function – the Generic Inter-Working Function, described below. Use case 2 assumes both RAN NC and RAN BS support Ethernet interfaces which means they can connect directly into a CEN. Both use cases 1 and 2 come in two flavors – with or without a legacy network option.



**Figure 2: Mobile Backhaul Implementation Agreement Use Cases**

Use cases of type 1 represent the current situation in mobile networks where there is a limited availability of elements with Ethernet interfaces, and most of the installed bases are based on TDM with some based on ATM. This situation is starting to change with Native Ethernet taking its place serving CDMA2000, UMTS/HSPxA, WiMAX and LTE, as depicted in use case 2.

## 6 Performance and Quality of Service requirements

### 6.1 Service Requirements

Typically a RAN backhaul consists of one to two RAN NC sites and between hundreds to thousands of RAN BS sites. In terms of bandwidth requirements for a single base station site, this may range from few Mbps to 100's of Mbps. Services defined for mobile backhaul need to be scalable, flexible and cost effective and to be compliant with the MEF defined services.

The relevant service types (port-based and VLAN-based) are E-Line, E-LAN and E-Tree. Replacing current lease line models with E-Line point-to-point service is a rather straight forward concept. E-LAN and E-Tree, on the other hand, require short explanations.

- E-LAN (multipoint-to-multipoint): Emerging Mobile 4G standards use flat IP architectures. This calls for inter RAN BS communication. In this case, it becomes useful to have sites that are on the same Local Area Network (LAN) and have equivalent performance.
- E-Tree (rooted multipoint): Traditionally in mobile backhaul the RAN BS sites only need to exchange data with RAN NC sites. This applies also for multimedia applications that require distribution of content to sites. This behavior is possible in an E-Tree service, where the RAN NC site is configured as root and the RAN BS sites are configured as leaves.

### 6.2 Traffic separation

Mobile standards defined by 3GPP, 3GPP2, and IEEE 802.16 identify user traffic classes on the radio interface. However there are no specific requirements for the backhaul. In addition to user traffic classes there is also synchronization, control, and signaling traffic between RAN BSs and RAN NCs, not to mention carrier control traffic in case of a leased service. Generally speaking, current mobile backhaul deployments rely on a single class of service (CoS) with a single availability class.

The MBIA provides guidelines for the number of CoSs to use, requiring at least two classes and recommending four classes, even though there is no limit on the number of CoSs a provider can use. These guidelines are based on a MEF initiated market survey, analysis of relevant mobile standard requirements - both current and future, and an analysis on how all of this is implemented in vendor equipment. More than that, the work took into consideration different relevant business models such as self owned backhaul or a leased backhaul service.

To simplify operations, bundling traffic classes into a limited number of CoSs is recommended. Table 2 shows examples of mobile backhaul classes mapped to CoS models.

Service Class Name	Example of Generic Traffic Classes mapping into Class of Service (CoS)		
	4 CoS Model	3 CoS Model	2 CoS Model
<b>Very High (H<sup>+</sup>)</b>	Synchronization	-	-
<b>High (H)</b>	Conversational, Signaling and Control	Conversational and Synchronization, Signaling and Control	Conversational and Synchronization, Signaling and Control , Streaming
<b>Medium (M)</b>	Streaming	Streaming	-
<b>Low (L)</b>	Interactive and Background	Interactive and Background	Interactive and Background

**Table 2 : Examples of MBH Traffic Classes mapping into 4, 3 and 2 CoS Models**

### 6.3 Ethernet OAM

Ethernet OAM requirements are not specified in any current mobile standards from 3GPP, 3GPP2, or IEEE, and normally are not implemented on mobile equipment. In general, the requirements are separated into Link OAM - monitoring of a single link, and Service OAM - spanning one or more links, both of which are recommended by the MBIA. Ethernet OAM is desirable for fault management, connectivity management, and performance monitoring of the Ethernet service. For example, Ethernet OAM for each subscriber EVC at the UNI could be implemented in the RAN NC and RAN BS to convey Ethernet connectivity state and performance. The MBIA refers to standards including Link OAM (IEEE 802.3ah), and Service OAM (both IEEE 802.1ag and ITU-T Y.1731).

## 7 Synchronization

For effective operation and performance, mobile networks, like most telecommunication networks, rely on the use of highly accurate Primary Reference Clocks (PRC) to distribute timing across all network elements. If the quality of the synchronization is unsuitable or degraded, the base station and mobile devices may lose "lock" or inter-cell handoffs may fail, resulting in dropped calls or degraded voice quality. There are three principal types of synchronization: frequency, phase and time, each of which has varying applicability to the various forms of 2G, 3G and emerging 4G mobile networks.

Frequency synchronization is particularly critical for today's GSM and UMTS base stations that derive their frequency from the core network and do not rely on Global Positioning System (GPS) based mechanisms for synchronization, as is the case for most CDMA networks which use frequency or time synchronization. For 4G networks, frequency and/or time synchronization

may be required at the base station, which is the case for various LTE operational modes (FDD, TDD, MBMS). In typical 2G/3G networks, base stations can derive synchronization from conventional PDH or SONET/SDH leased lines used to backhaul the traffic. In most applications for mobile networking, a frequency accuracy of 50 parts per billion is required. Standards define the permissible output jitter and wander for traffic and synchronization interfaces, which are defined in the ITU-T G.823/G.824/G.825 specifications. Packet based backhaul networks must also meet these requirements to provide a reliable and predictable connectivity to the synchronization source.

Since Ethernet is an asynchronous transport technology which does not natively provide any synchronization services on its own, various standards bodies have been working to overcome this challenge. The ITU-T released a key recommendation in April 2006, ITU-T G.8261 (Timing and Synchronization Aspects in Packet Networks) to address this. The result has led to two approaches for synchronization in packet-based networks which are based on either physical-layer or packet-layer methodologies.

The first approach distributes timing (frequency) at the physical layer and requires embedding a clock distribution signal in the line code, similar to the synchronization method currently used in SONET/SDH networks. This method is referred to as 'Synchronous Ethernet'. While extremely accurate, Synchronous Ethernet has the drawback of being required in each node in the network for end-to-end network synchronization. Because Synchronous Ethernet is considered an emerging technology, it is not defined in Phase 1 of the MEF MBIA but is being planned for future study.

The second approach distributes timing (frequency and/or time) in the packet layer using a dedicated IP/Ethernet packet stream. Packet based methods may be based either on timestamp exchanging protocols (IEEE 1588v2 Precision Time Protocol or IETF Network Time Protocol), or on the packet inter-arrival times. In the first case, base stations can use the timestamps of the received packets to reconstruct the original time and frequency information to a given accuracy by using sophisticated algorithms. In the second case, base stations can use the inter-arrival time of the received packets to reconstruct the original frequency information to a given accuracy by using Adaptive Clock Recovery (ACR) methods.

The packet-based approach results in synchronization that is independent of the physical layer, and is flexible to interoperate with a wide variety of access transport layers including fiber, copper, microwave etc. However, unlike physical layer timing distribution, this technique is vulnerable to packet network impairments such as end-to-end delay, delay variation and frame/packet loss. This is where the benefits of a deterministic Carrier Ethernet Network (CEN) become an effective means for supporting packet-based synchronization. The MEF MBIA recommends that when using packet-based methods (timestamps protocols or ACR methods), it is preferable to carry timing over a well engineered CEN, with the timing flow carried in a channel assigned the highest level of priority to minimize packet network impairments.

Within the current scope of the MBIA Phase 1, synchronization requirements are provided for TDM based interfaces as specified in ITU-T G.8261. These include recommendations to ensure that the method of synchronization meets the jitter and wander requirements for common TDM interfaces, including E1/DS1 and E3/DS3 circuits, being transported over the CEN, to support mobile backhaul applications.

## **8 Generic Inter-working Function (GIWF) and Supporting MEF Services**

The mobile backhaul Generic Inter-Working Function provides adaptation and interconnection between TDM-based mobile equipment in the RAN BS and RAN NC, and the interface to the Carrier Ethernet domain. It enables the backhaul of any combination of 2G, 2.5G, 3G (legacy based) and Evolved-3G & 4G (Ethernet based) voice and data traffic over a single Carrier Ethernet RAN. The adaptation of the legacy mobile traffic to the CEN service is based on MEF 8 CEsSoETH (SAToP/CEsSoPSN), IP/MPLS Forum 20, ATM PWE3, and Frame Relay/HDLC PWE3 over a single pipe. With respect to synchronization, the GIWF may contain functions to support synchronization over the CEN.

### **8.1 MEF 8, 18 (Circuit Emulation Services)**

Circuit emulation services (CES) is a major step in the industry's progression toward entirely converged networks as it enables the transport of TDM services over Carrier Ethernet services. MEF 8 was designed to meet these challenges, while MEF 18 is designed to certify conformance. The proposed transition path relevant to mobile backhaul is to carry legacy voice and data traffic via TDM and CES over Carrier Ethernet while data growth is handled by Carrier Ethernet. Both traffic streams are expected to merge over time.

### **8.2 IP/MPLS Forum 20 (MPLS in Mobile Backhaul Networks)**

The MPLS backhauling of Ethernet, TDM and ATM circuits is being defined by the IP/MPLS Forum. The MEF liaises with the IP/MPLS Forum to ensure the specifications are aligned. For more information, please consult the forum's "MPLS in Mobile Backhaul Networks Framework and Requirements Technical Specification", published in October 2008.

## **9 Summary**

We hope after reading this paper you have an understanding of the Mobile Backhaul Implementation Agreement and how it can be used as a guide to implementing Carrier Ethernet for Mobile Backhaul.

## 10 Appendix: Disclaimer, References, Acknowledgements

### 10.1 Terminology

Term	Definition
ATM	Asynchronous Transfer Mode
CEN	Carrier Ethernet Network
CES	Circuit Emulation Service
CESoETH	Circuit Emulation Service over Ethernet
CESoPSN	Structure Aware TDM Circuit Emulation Service over Packet Switched Network
CoS	Class of Service
E-LAN	Ethernet LAN
E-Line	Ethernet Private Line
E-Tree	Ethernet Private Tree
EVC	Ethernet Virtual Connection
FDD	Frequency Division Duplex
GIWF	Generic Inter-working Function
HDLC	High Level Data Link Control
IEEE	Institute of Electrical and Electronics Engineers
ITU-T	International Telecommunications Union Telecommunication Standardization Sector
LAN	Local Area Network
LTE	Long Term Evolution
MBIA	Mobile Backhaul Interface Agreement
MBMS	Multimedia Broadcast Multicast Service
MEN	Metro Ethernet Network (Note The term Carrier Ethernet Network may be used interchangeably)
OAM	Operations and Maintenance
PRC	Primary Reference Clock
PWE3	Pseudowire Emulation Edge to Edge
RAN	Radio Access Network
RAN BS	RAN Base Station
RAN CE	RAN Customer Edge
RAN NC	RAN Network Controller
SAToP	Structure Agnostic TDM over Packet
TDD	Time Division Duplex
TDM	Time Division Multiplexing
UNI	User Network Interface
WiMAX	Worldwide Interoperability for Microwave Access
3GPP	3rd Generation Partnership Project

### 10.2 References and Resources

"Mobile Backhaul Implementation Agreement Phase 1 (MEF 22)"	<a href="http://metroethernetforum.org/page_loader.php?p_id=29">http://metroethernetforum.org/page_loader.php?p_id=29</a>
"Carrier Ethernet Access for Mobile Backhaul Networks"	<a href="http://metroethernetforum.org/page_loader.php?p_id=30">http://metroethernetforum.org/page_loader.php?p_id=30</a>
"Metro Ethernet Services – A Technical Overview"	<a href="http://www.metroethernetforum.org/metro-ethernet-services.pdf">http://www.metroethernetforum.org/metro-ethernet-services.pdf</a>
"MPLS in Mobile Backhaul Networks Framework and Requirements Technical Specification"	<a href="http://www.ipmplsforum.org/tech/IPMPLSForum20.0.0.pdf">http://www.ipmplsforum.org/tech/IPMPLSForum20.0.0.pdf</a>

### 10.3 Disclaimer

This paper is subject to change without notice. The paper does not necessarily represent the views of the author or author's commercial affiliations.

### 10.4 Acknowledgement

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### 10.5 About the MEF

The Metro Ethernet Forum (MEF) is a non-profit organization dedicated to accelerating the adoption of carrier-class Ethernet networks and services worldwide.

The Forum is comprised of leading service providers, major incumbent local exchange carriers, top network equipment vendors and other prominent networking companies that share an interest in Carrier Ethernet. As of January 2009, the MEF had over 150 members.

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<sup>i</sup> Mobile Backhaul Equipment, Installed Base, and Services Biannual Worldwide Market Size and Forecasts, October 27, 2008, Infonetics Research