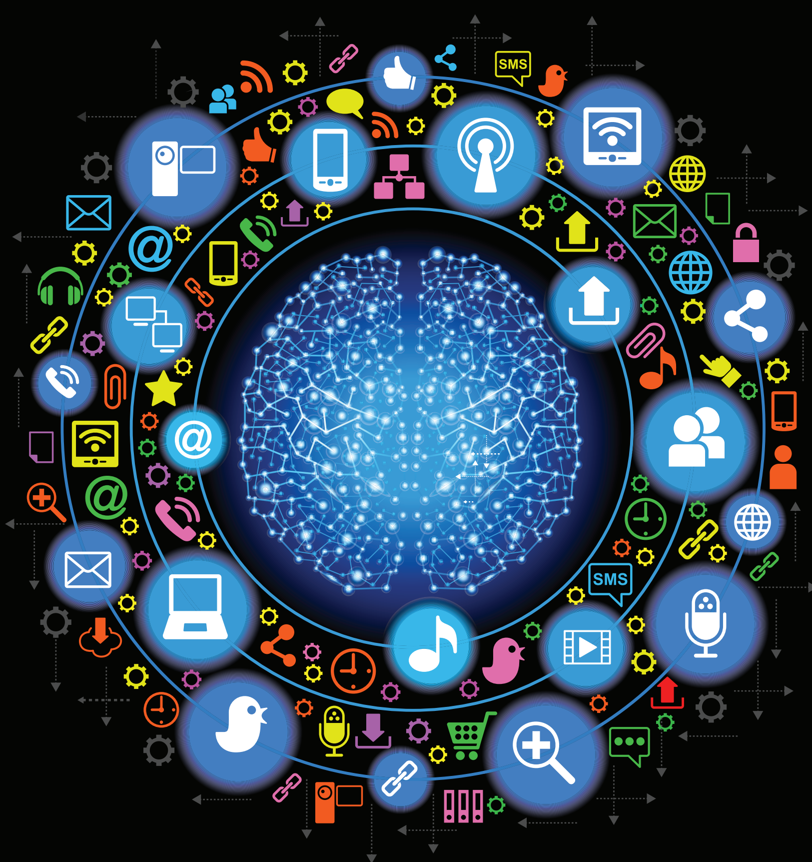
evolution to content optimized networks



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Evolution to Content Optimized Networks

The ongoing research, development, and standardization of named content networking solutions will offer network operators, and the larger content ecosystem, an opportunity to fundamentally change the current paradigm for how content is discovered, delivered, and consumed by devices, people, and things. Over the last few decades, IP networks have leveraged a broad range of IP point solutions and overlays to meet the growing demands of mobility, content delivery, and new applications. From a practical standpoint, the evolution to Content Optimized Networks (eCON) could be achieved through a number of different deployment paths, timelines, architectural approaches, and technology choices. This report summarizes a technology assessment undertaken by the Alliance for Telecommunications Industry Solutions (ATIS) and provides a basis for understanding the current network challenges, drivers for evolution, architectural alternatives, and target opportunities for early deployment.

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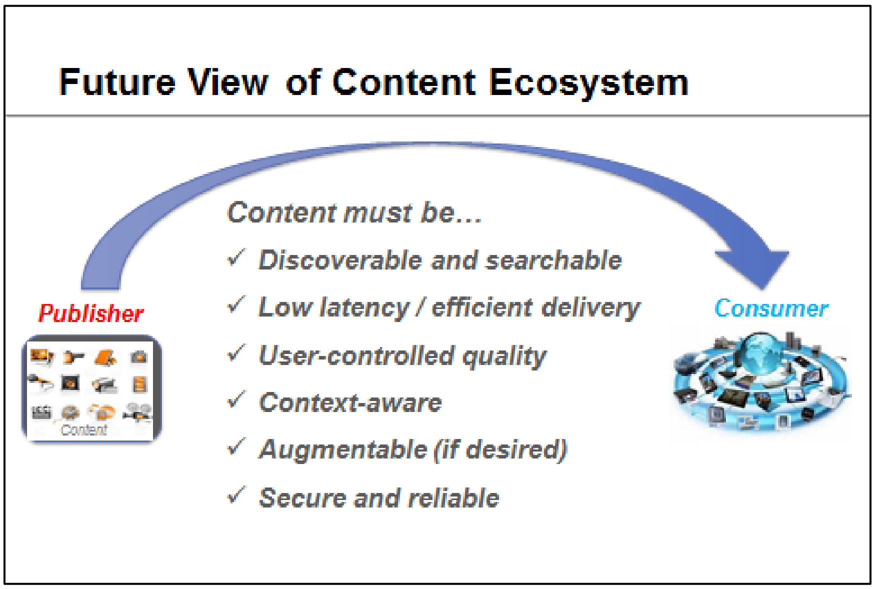
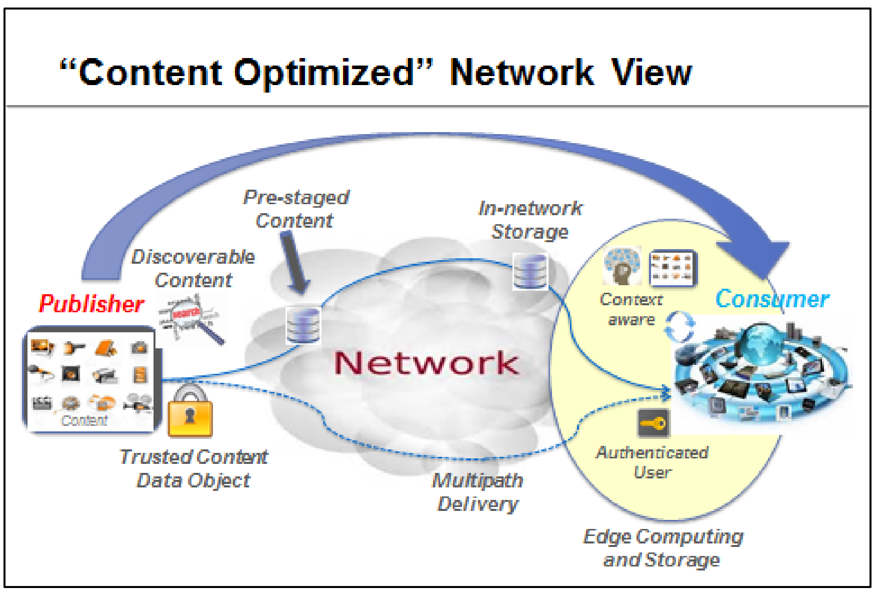
What are Content Optimized Networks?

As the market continues to evolve to a data and information-centric model, network operators are exploring new architectural options that recognize the role that content will play in the future set of services and applications. In this respect, content can be viewed as a simple relationship between a content producer and a content consumer. The attributes that define this relationship are illustrated in the following diagram:



Translating this future state vision of a content ecosystem to a network context is the instantiation of a content optimized network. Content becomes defined by data objects, which are discoverable and searchable, and may utilize in-network storage. The objects themselves must be secured through a trust and security model that validates the content and assures that the content is accessed by an authenticated user. Content may be pre-staged or stored at any point in the network, or may be processed near the edge of the network, depending on the application. Furthermore, the ability to utilize multipath delivery can overcome congestion and latency challenges. As the nature of content becomes more contextual and augmentable in the future, many versions of the same content must be accessible and delivered in a high-bandwidth and low-latency manner. Therefore, content optimized networks are based on the premise that current approaches to delivering content must evolve from a basic source and destination model (that is the underlying principle in today's IP networks) to an architecture that is optimized for non-persistent connectivity (mobility), multi-path delivery, dramatically increasing number of content origination points and devices, and a new security approach that protects the content object.



Current Network Challenges

Today's IP-based networks are defined by a connection-oriented architecture that has evolved through a series of IP point solutions and overlays to meet the changing market demands. Network challenges do not necessarily imply that current networks cannot meet future demands or must be replaced in an end-to-end manner. The fundamental question is whether current network architectures are truly optimized to meet the future needs of the content-centric marketplace.

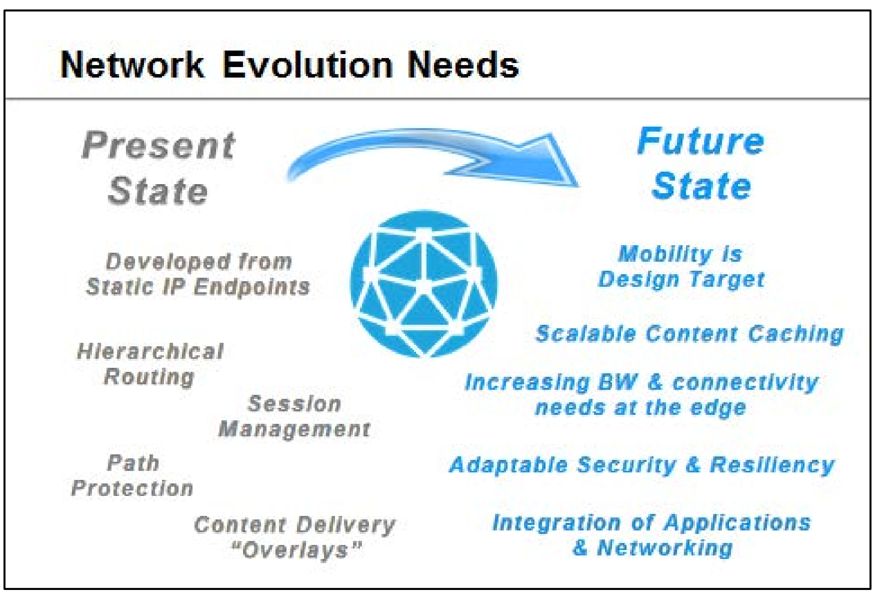
The pervasive deployment of IP networks by mobile and fixed service providers and content delivery network (CDN) operators represents an ongoing evolution of architectures and protocols intended to: increase network efficiency; lower the costs of delivering communications and content-based services to the end user; and create a better user experience across a broad range of services (including premium content, over the top services, and Internet-based applications). To this end, operator networks have deployed new infrastructure and architectural solutions, including:

- *Transparent Proxies/Caches* – Intermediate systems that process requests, store content, apply policy, and forward frequently requested content.
- *Content Delivery Networks* – Rely on geographically dispersed servers to speed the delivery of content, thereby minimizing latency and mitigating Internet bottlenecks.
- *Open Caching* – Utilize shared caching resources implemented in the operator's network and within close proximity to consumers.

In addition, there have been a number of TCP/IP enhancements driven by the needs for enhanced user experience, which have resulted in IP-based protocol evolutions and point solutions, including HTTP2, IPv6, Quick UDP Internet Connections (QUIC), and Location Identifier Separation Protocol (LISP). The resulting improvements have been manifested by lower latency, faster downloads, better mobility support, and improved user experience.

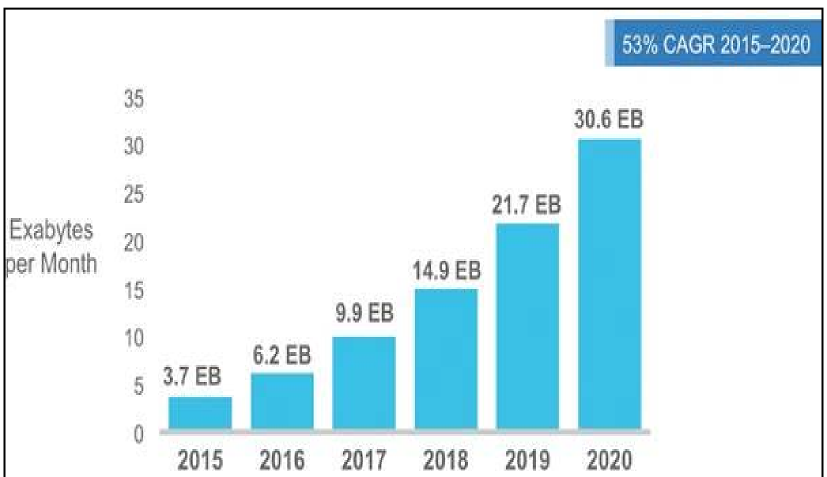
Therefore, the fundamental question is: *Can IP-based networks continue to evolve in a sufficiently robust manner to meet the future challenges of massive edge content, IoT sensors and devices, content rich and context-aware services, and the rapidly expanding mobile video market?*

The following is an illustration of the basic design components of the current IP networks vs. the characteristics of a future state content optimized network:



Although current networks continue to evolve to meet new requirements and demands, there are inherent challenges that will impact future network design choices. Connection oriented networks are becoming increasingly challenged as the market becomes dominated by non-persistent connectivity (i.e., mobility).

For most mobility applications, networks depend on IP encapsulation and tunneling. In the future, 5G solutions will demand significant network efficiency improvement to meet the goals of higher bandwidth and lower latency. Given the fact that IoT sensor-based networks will become more pervasive, service providers will likely explore alternative solutions that are less constrained by the addressing, routing, and forwarding elements of IP networks. As the content environment evolves, existing flow control and session management mechanisms may not be sufficient, particularly for interactive, real-time applications.



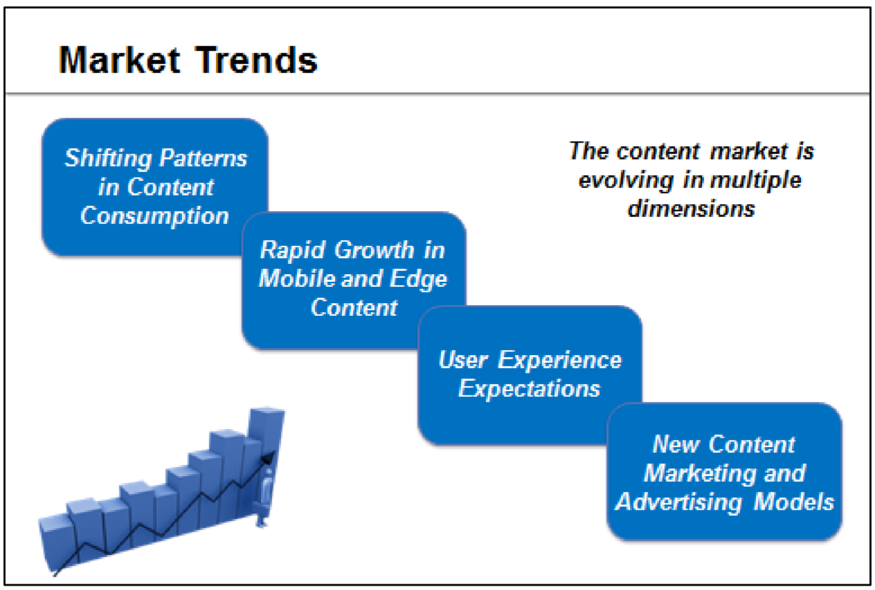
Source: Cisco VNI Mobile Data Traffic, 2016

Perhaps the greatest challenge to existing networks is the caching of content. In the evolution of wireless networks, caching of high-interest content will be dependent on the ability to identify the most requested content and the capability of the radio access networks (RANs) to store and deliver the content in an optimized manner. At a more fundamental level, the current caching of content in edge server solutions is severely limited by end-to-end encryption for unmanaged (e.g., Internet) content. Solutions that leverage in-network caching of content and provide better solutions to support pre-staged content will offer significant opportunities in the future.

Future Trends and Market Drivers

Recent trends in the market have shown that the industry cannot assume a traditional view of network growth, as new networks, devices, and applications are impacting how people, things, and processes ultimately connect and leverage information.

The future state of the network will be shaped by both market-based drivers and technology-oriented trends. It is abundantly clear that the content market is creating new demands and that these trends are occurring in multiple dimensions.



An assessment of the changing content market yields the following key trends:

Content Consumption

- New media devices impacting the market.
- Migration to over-the-top services.
- Growth of live streaming.
- Expanding base of original content.
- Social media acting as an amplifier of content.
- Shelf life of content varies across applications.

Mobile and Edge Content

- Mobile-driven consumption outpacing the market.
- Content digestible across range of mobile devices.
- Content transferrable over different media devices.
- Flexibility to act on content at the edge.
- Ability to handle machine-generated content.
- Dynamic consumption of content.

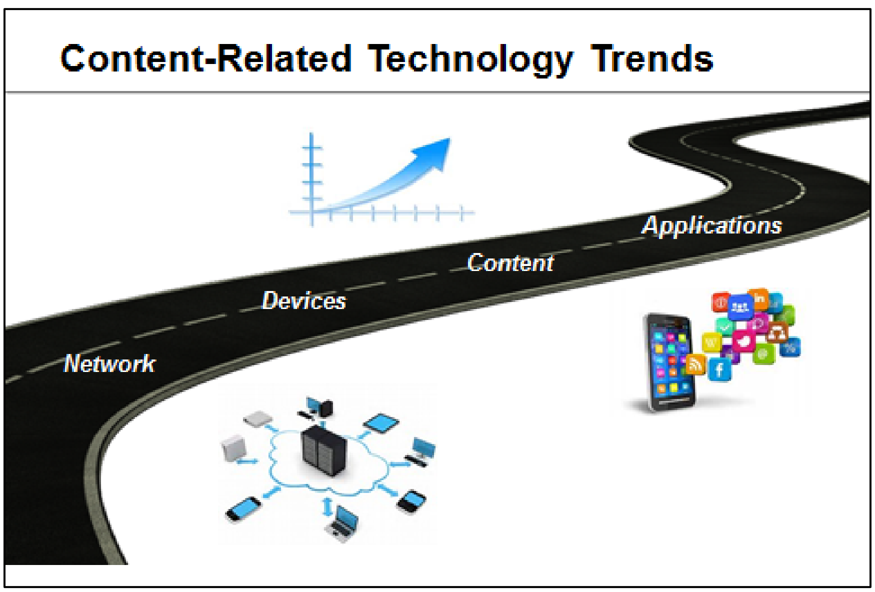
User Experience Expectations

- Ability to translate UX across many devices.
- Preference for video and infographics (vs. text).
- Higher video quality expectations (HD, 4K, 8K).
- More user control and customization of content.
- Greater responsiveness to dynamic events.
- Evolution to a more cognitive experience.

Content Marketing and Advertising

- Finding the content is the ultimate goal for producer and consumer.
- New solutions embedding ads with content.
- Augmented content tailored to end user.
- Social media providing new distribution means.
- Content marketing for "things".
- Consumers want more choice in how content is accessed:
    - Less dependence on subscription models.
    - Layers of access based on interest level.
    - Dynamic visibility to augmented content.

In addition to key market drivers, technology and networking trends are laying the groundwork for dramatically new approaches to delivering and acting upon content.



Network Trends

- Flattening of the network.
- Network virtualization and data center expansion.
- Software-defined networking.
- High bandwidth/low latency access networks.
- Continued growth of cloud networks.
- Content owners deploying their own networks.
- Emergence of shared/community based delivery.

Device Trends

- Internet of Things evolving to Internet of Everything.
- New connected devices leveraging machine intelligence.
- Parallel processing blocks and higher clock speeds.
- More storage and memory on user devices.
- Low Power WAN devices.
- More rich Internet applications to new devices.
- Device security inherently “designed in”.

Content Trends

- Higher compression rates with better quality.
- End-to-end encryption.
- Content device adaptable (with user control).
- New sources will dramatically increase pushed data.
- Better solutions for indexing and discovering content.
- Content owners control of consumption and context.

Applications Trends

- People leveraging technology shifts to cognitive-based technology that emulates people.
- Applications increasingly embed advertising.
- New security challenges with edge data.
- Mixed, augmented, and mediated reality applications.
- Shorter cycles to adoption of new application types.
- Open source is viable option for software development.

Current Research and Development Activities

ICN Principles

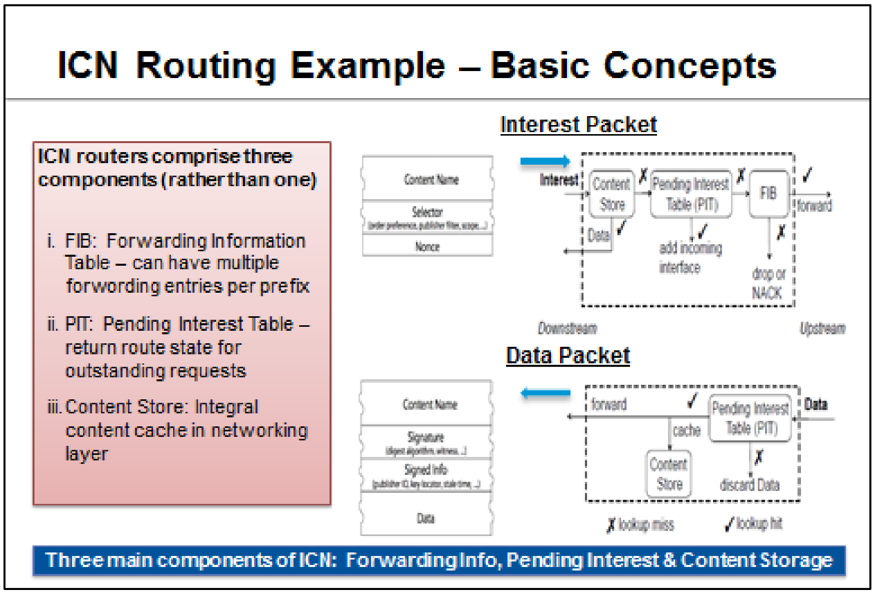
Early research on content-naming architectures began over a decade ago. Most of development has focused on a class of solutions known as Information Centric Networking (ICN). ICN is broadly defined as an approach intended to evolve Internet architecture away from the existing host-centric dependency to an architecture that is based on naming information and treating content as data objects. A particular content object is not tied to a particular host or address, but may be present in multiple locations in the network. The content object is delivered to a prospective consumer who requests it, by name, without consideration of where the requested object may be found at the time of the request.

Some of the key differences between TCP/IP and ICN architectures are illustrated below:

TCP / IP – ICN Comparison

TCP / IP	ICN
Packet switching / routing	Packet switching / routing
Addresses Hosts	Addresses data (No source addresses!)
Reliable / unreliable transports	No discernable transport
Asymmetric routing	Symmetric routing
Stateless forwarding	Per-packet state during request forwarding
Channel-oriented security (IPSEC, SSL)	Object security
Unicast / Anycast / Multicast	Multipoint-Multipath Request / Response
Mobility Support via tunneling overlay	Implicit mobility support
Content delivery optimization via CDN overlay	Natural multipoint delivery from in-network caches

ICN routing principles rely on three routing components: (1) Forwarding Information Table, (2) Pending Interest Table, and (3) Content Store. In addition, there are two types of ICN packets: Interest Packet and Data Packet. Each of these components is defined below:



The basic principles of ICN can be summarized as follows:

- Name-based network operations.
- Request-based multipath connectionless transport.
- Symmetric routing (coupled to request-response model).
- Stateful forwarding → in-network control.
- In-network storage.
- In-network processing.
- Object-based security, not connection-oriented.

A number of industry efforts are underway to further develop and standardize ICN-based architectures and protocols. There are two general classes of ICN approaches that have somewhat diverged, but are now under some initial stages of harmonization:

CCNx (Content Centric Networking) - An ICN architecture, the CCNx project was announced by PARC publishing interoperability specifications and an open source implementation in 2009. Some aspects of CCNx have been subsequently published in IETF drafts.

NDN (Named Data Networking) - An ICN architecture, the NDN project includes research funded by the National Science Foundation across many academic and industry institutions, including Center for Applied Internet Data Analysis (CAIDA [referenced in this report]). Ongoing research has led to a growing code base for NDN.

ICN Research and Standards

There have been a number of academic and industry-based standards initiatives related to ICN. Some of the more significant standards-related work to date on ICN includes:

IRTF Research Group (ICNRG)

- CCNx 1.0 protocol specification is a Research Group document (compilation of 5 documents).
- Moving towards publication as Experimental RFCs.

IETF – Working Group plan

- Harmonization efforts for CCN and NDN underway.
- Joint specifications targeted for 2017.

ITU-T SG13 Focus Group IMT-2020

- Exploring standardization gaps for non-IP protocols.
- Extending gap analysis to prototypes and proof of concepts.

3GPP 5G Core Standards

- SA2 completing study of 5G core requirements in early 2017 followed by 1-2 years of normative standards.
- ICN-related goals are being assessed.

CAIDA and NDN Team

- Collaboration on a new NDN architecture that is based on distributing content.
- New security model is key component, as security is applied to the data itself vs. securing the container.

NIST Advanced Network Technology

- Hosting workshops on Named Data Networking.
- IoT is one key interest area.

In addition to standards and research activities, ICN-based solutions have been undertaken by various academic/public partnerships, and have resulted in some early prototyping and testing initiatives.

The Mobility First Future Internet Architecture Project is a collaboration of several prominent universities exploring the use of an advanced protocol stack to test and evaluate a range of mobile data, content and IoT use cases. Prototype testing, being conducted by Rutgers University WINLAB, is utilizing a structure of globally unique identifiers (GUID) associated with public keys to support an architecture defined by named objects, global name resolution, and in-network storage and computing across a range of IoT applications.

Object-Based Objects and Security Trust Model

Traditional communications security models encrypt the "connection" (after authentication/authorization), e.g., HTTPS/HTTP2 leverages TCP session with TLS. If the object (not the session) is considered, a number of potential improvements can be achieved:

- Better manage the traffic in the network, since the objects are independent, allowing more controlled network/link load balancing.
- Cryptographically sign the data object ensuring integrity and authenticity.
- If needed, the application can also encrypt the object for access control and/or DRM purposes.

These improvements could translate into a number of benefits to network operators, content owners, and end users. Given that all data objects are signed, the network could "firewall" unauthorized content (potentially on a selective basis, based on triggers). Additionally, this would allow priority of data objects, e.g., in the case of government priority services. There is also the potential to achieve better malware detection/mitigation and Distributed Denial of Service (DDoS) protection.

As ICN standards continue to progress, the industry will also need to answer the key question of what new vulnerabilities might be created with an ICN architecture. For example, how to prevent flooding the network with interest packets based on predicted object names. The solution may be equivalent to an IP Access Control List (ACL), a security technique used today to diagnose a sudden increase in traffic and take appropriate action to block suspicious traffic.

As ICN evolves, the development of an ICN Security Trust model will be a key foundational element. Of course, there are strong relationships between the security trust model, and naming schemes, routing, and ICN packet parameters. The security and trust issues extend beyond the fact that data objects must be signed, as there will be object-based privacy and access issues to be resolved. Given the important role that content will play in future applications, the development and content ecosystem acceptance of an ICN Security Trust model will have to integrate cryptographically defined trust models with user behavioral-based trust assumptions to achieve an optimized and highly secure solution.

ICN Naming

The naming characteristics of ICN architectures are still being defined, and are somewhat outside of current protocol developments. ICN naming does remove the constraint that packet labels can only identify communication endpoints. ICN names can identify anything (e.g., video chunks, real-time voice segments, commands to an IoT device, or endpoints). In theory, the naming schema is set by the application design, as names are opaque to the network. Names can be defined with a specific scope and context, and may have local or global meaning, but are unique within their designated scope.

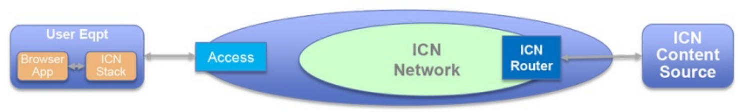
Naming strategies are a topic of current research, in terms of how applications define names that facilitate both application development and network delivery. In CCN and NDN, there is the concept of a hierarchically structured object label. As referenced earlier in this report, Mobility First is exploring the characteristics of named devices, content, and context, and the concept of using globally-unique identifiers to define all network objects. Their approach is to use flat public keys as the global identifier vs. a hierarchical semantic identifier.

It is understood that ICN naming will present challenges, as long content names can be encountered, but very large namespaces will need to be addressed in an appropriate manner. One important question with respect to naming is the aspect of name management, which in ICN could be exclusively done by application providers, network administrators, or both. The flexibility to support both secure and contextual names, along with considerations such as applications' need to replicate and handle mobile resource objects, offers a scalability challenge that must be addressed. Over the next few years, it is expected that ICN naming approaches will continue to be explored from both an architecture and prototype testing perspective.

Application Analysis – HTTP-based Services with ICN

A key component of an ICN assessment is the manner in which named objects can be applied to HTTP-based services. The implications, especially in the context of http namespace, are summarized below:

Supporting HTTP-Based Services with ICN
An Example



- Assume:
  - Configuration shown above – Browser (app) using ICN to run "HTTP" services.
  - Start with a known name (e.g., www.atis.org)
- Key Point: There is a distinction between named objects that are meaningful to the http application and named-objects that are meaningful to the ICN network. The task then becomes how to translate the application names into network names (e.g., via a manifest). In the future, the namespace of http could be constructed to work better with an ICN network.

A detailed assessment of the challenges that must be addressed for HTTP-based applications yields the following key issues:

- Aggregation: Dealing with individualized content and "cookies".
- Caching: It is likely that the individual ABR segments for a content (video) item, icons, images, fonts, javascript files, and CSS files may well be cacheable.
- Redirections: Must solve the advertising use case where content location may not directly be known by a redirecting site (i.e., multiple redirections may occur).

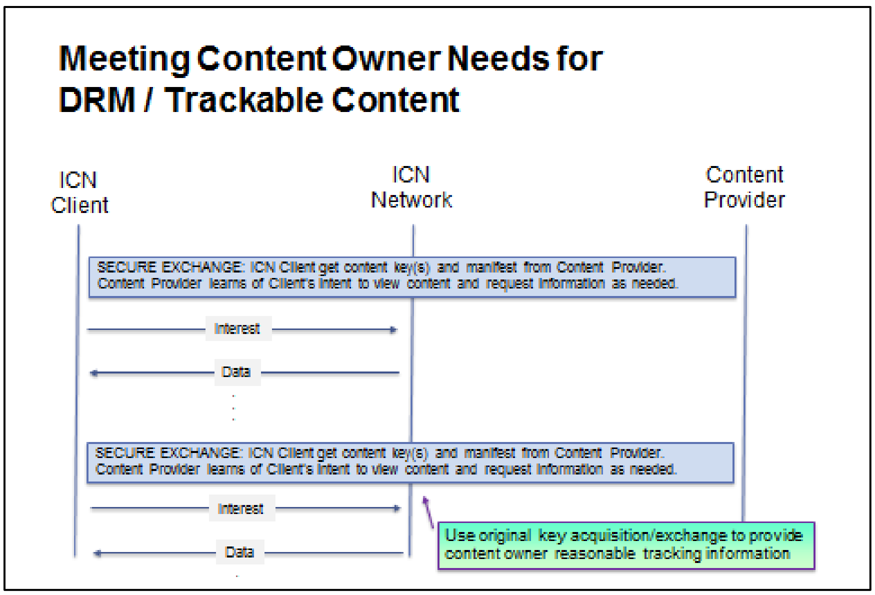
- Measurements: Measure who requested and/or how many requests have been received for a resource.
- Push: Enable pre-fetch of assets.
- Purging cached content for take-down due to copyright issues or inaccuracy of data.

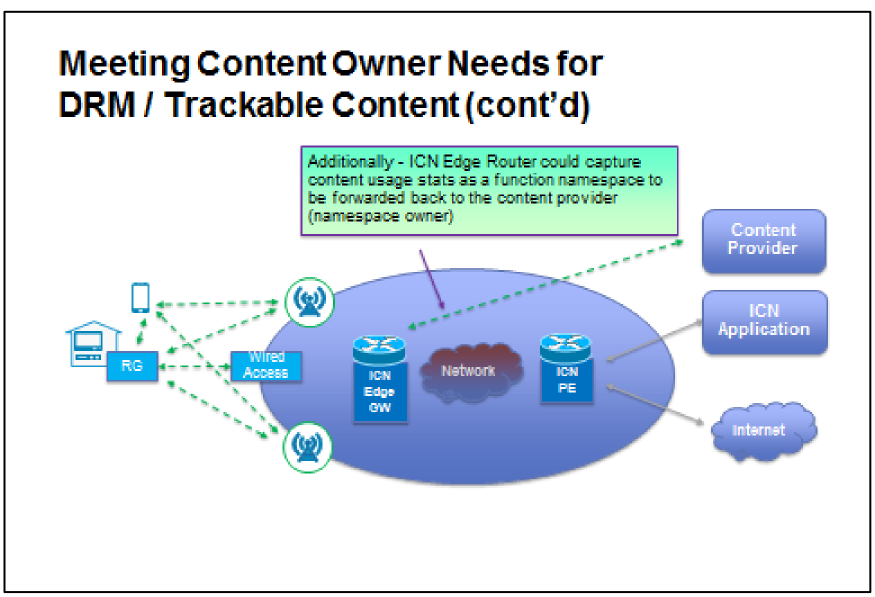
Each of these parameters was reviewed in terms of likely resolutions and/or needs (in terms of future development). The following is a summary of the preliminary findings related to HTTP-based applications:

Key Issue	Comment
Aggregation of Interest packets in dealing with individualized data/cookies	Individualized data/cookies would not be aggregated but, although more research could be done, a large percentage of HTTP applications appear to include a large number of assets that can be aggregated/cached. **Need efficient mechanism in ICN to include large amounts of data in a request.**
Caching of objects	Rich set of assets can be cached including ABR segments, icons, images, fonts, javascript, css, etc.
Redirections	Redirection can be done in the application layer as it is done today with HTTP. Alternatively, the "link" method in ICN/CCN/NDN can be used for redirection. However, since NACK does not exist in ICN, additional work may be needed to consider the consequences of non-existent objects.
Measurements	**HTTP / ICN pages / content should be crafted with measurement objects chosen to maximize network cache efficiency.**
Push	The effect can be managed at the application layer with for example, manifest files and other means (Firewalls prevent autonomous push operations today in general). Additionally – other "All in One" proposals have been forwarded to address this more natively within CCN / ICN.
Purging cached content	Require use of an ExpiryTime in the Data Object or a new "ClearCache (name, signature)" method within ICN **Additional study needed on cache life / purge requirements and solutions.**

Application Analysis – DRM Trackable Content

ICN could provide a key opportunity to content owners with respect to trackable content. The acquisition of the content key by the ICN client could provide valuable information to a content provider of DRM-based content. This data could be further enhanced by utilizing an ICN gateway to collect usage statistics (under appropriate privacy and confidentiality rules) and deliver relevant information back to the content provider. This application is summarized in the following slides:





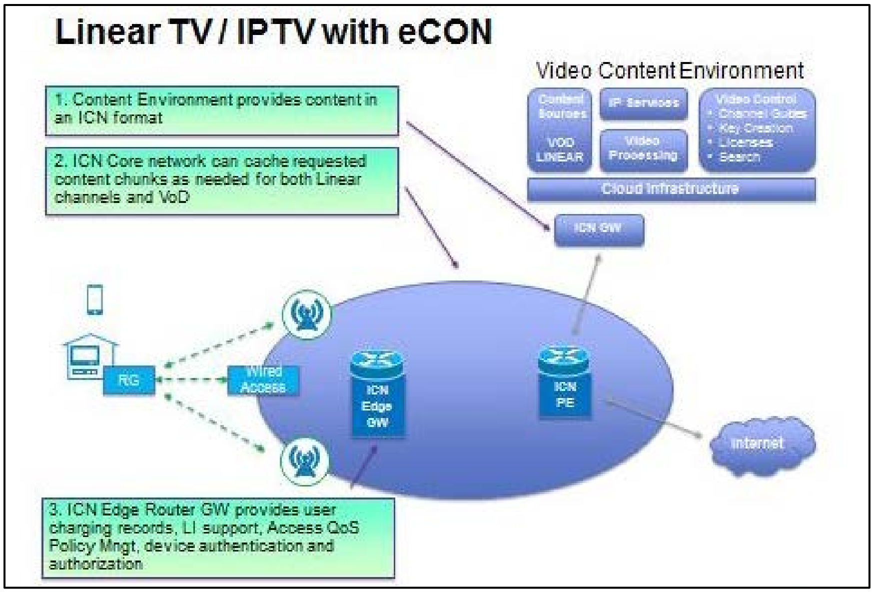
Assessment of Early Deployment Opportunities

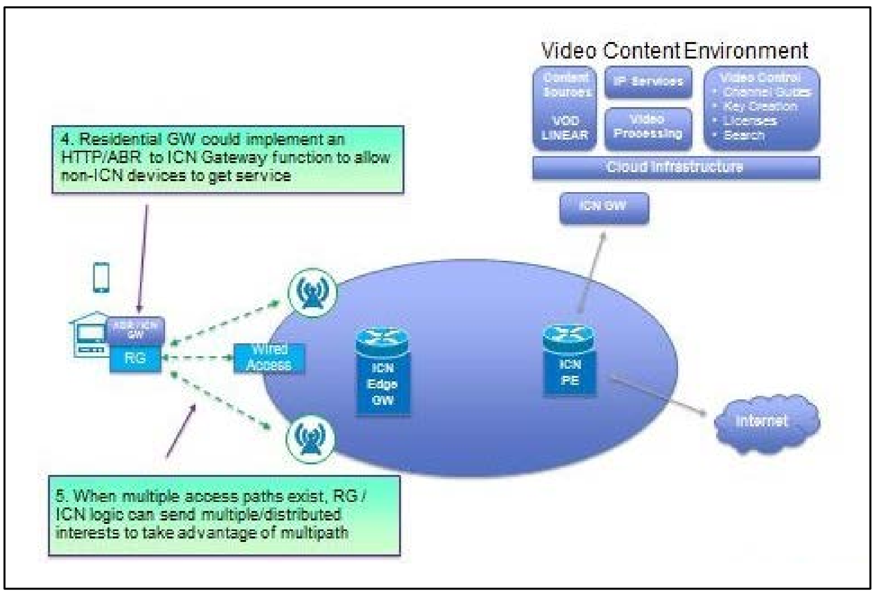
Similar to prior network transformation activities, the evolution from today's IP-centric architectures to an ICN-based architecture could be achieved through a range of incremental overlays, or could adopt a more disruptive end-to-end approach. This analysis has reviewed a number of potential target opportunities and identified an initial set of use cases that could leverage ICN solutions. In some scenarios, the use cases represent specific applications, and in other scenarios the use cases represent more general functions or capabilities (e.g., multipath) that could be applied to a broad range of network solutions.

The following is a list of potential target opportunities, including an assessment of how ICN-based solutions would impact architecture designs:

1. *Linear TV / IPTV with eCON*

This application provides replacement architecture for unicast-delivered entertainment services. It assumes an ICN gateway connection to a video content environment that provides content to the core network in an ICN format. A residential gateway could be implemented at the customer location to accommodate non-ICN devices and avoid consumer device impacts. The residential gateway could leverage multipath support from wireless and wired last mile access options.

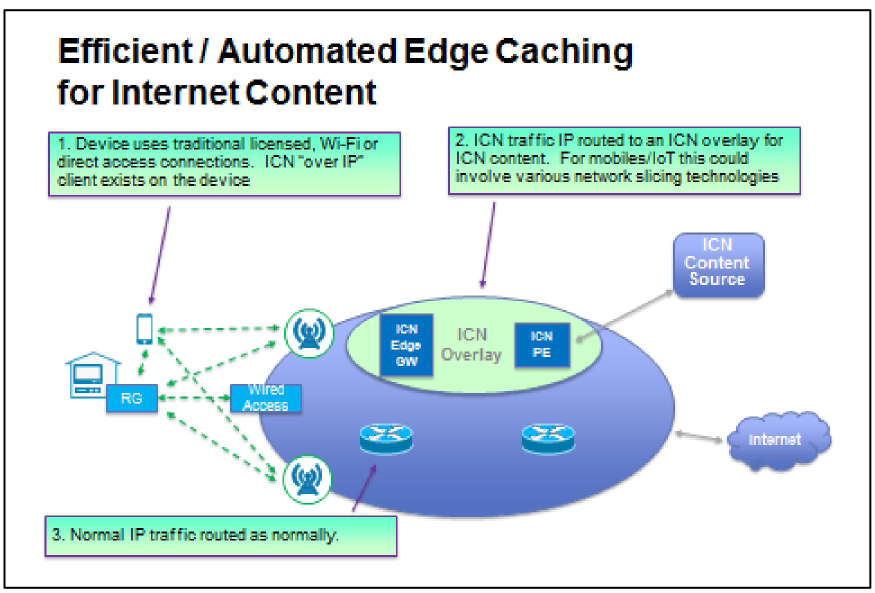

Linear TV / IPTV with eCON
Video Content Environment
Content Sources
VOD LINEAR
IP Services
Video Processing
Video Control
• Channel Guides
• Key Creation
• Licenses
• Search
Cloud Infrastructure
ICN GW
1. Content Environment provides content in an ICN format
2. ICN Core network can cache requested content chunks as needed for both Linear channels and VoD
RG
Wired Access
ICN Edge GW
ICN PE
Internet
3. ICN Edge Router GW provides user charging records, LI support, Access QoS Policy Mngt, device authentication and authorization


Video Content Environment
Content Sources
VOD LINEAR
IP Services
Video Processing
Video Control
• Channel Guides
• Key Creation
• Licenses
• Search
Cloud Infrastructure
ICN GW
4. Residential GW could implement an HTTP/ABR to ICN Gateway function to allow non-ICN devices to get service
RG
Wired Access
ICN Edge GW
ICN PE
Internet
5. When multiple access paths exist, RG / ICN logic can send multiple/distributed interests to take advantage of multipath

2. Efficient / Automated Edge Caching for Internet Content

This application assumes the use of an ICN over IP client on a consumer device and the existence of an ICN overlay in the network to allow ICN traffic to be connected between an ICN content source and end user device. In this case, traditional IP traffic is routed over existing IP routing infrastructure.

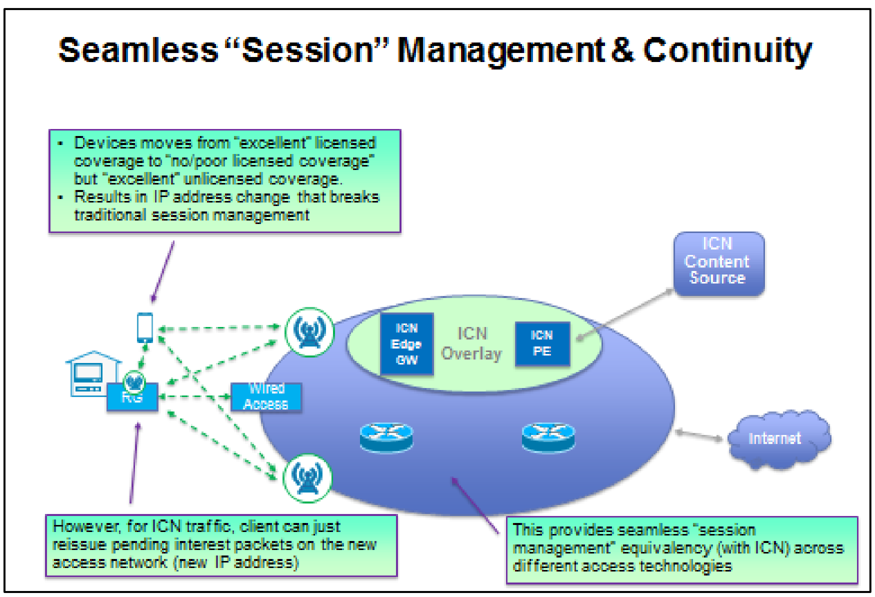
A key aspect of this architecture is the capability to utilize network slicing technologies when the connecting device is ICN-capable, e.g., mobile or IoT device. Network slicing refers to the ability to run multiple logical networks as a virtually independent business operation on a common physical infrastructure. Network slicing goes hand-in-hand with SDN and NFV by allocating traffic to resources, and hence can operate at many levels of granularity.



3. *Seamless "Session" Management and Continuity*

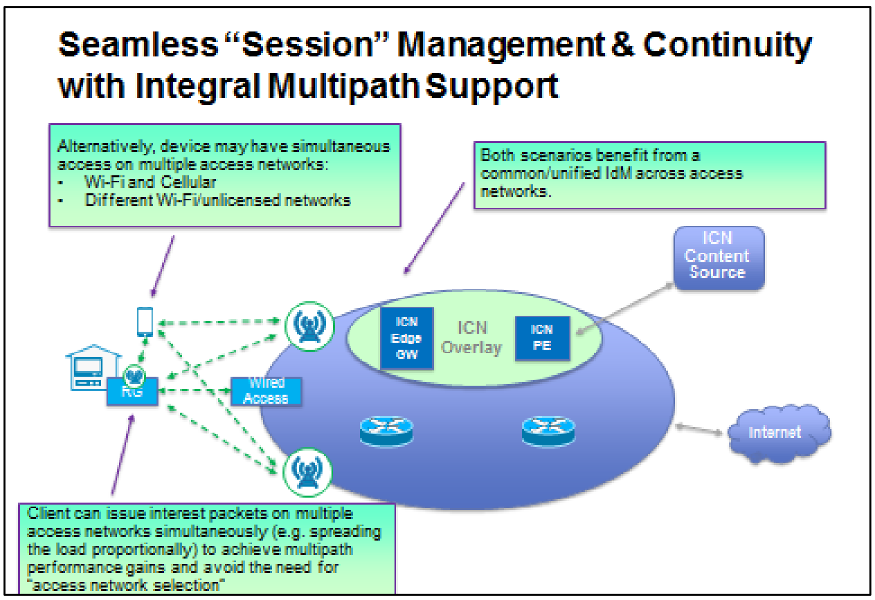
This application emulates session management (a term associated with connection-oriented architectures). This use case requires a change of an IP address change which negatively impacts traditional session management, particularly for real-time applications.

In this application, devices can move between various licensed and unlicensed (and wired access) to achieve better performance or quality. For ICN traffic, the client can re-issue pending interest packets across the new access network to maintain seamless management and produce a desirable user experience.



4. *Integral Multipath Support*

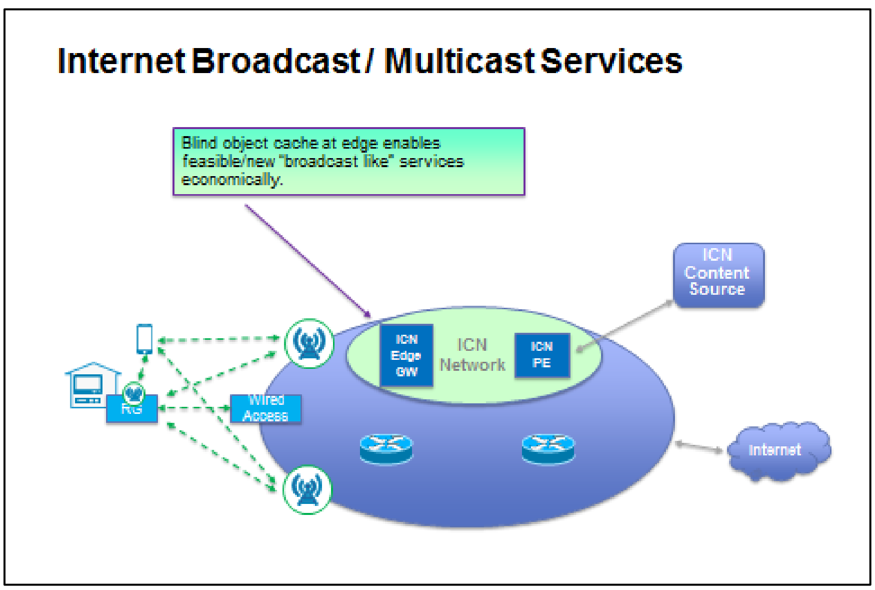
An extension of the previous example to accommodate simultaneous use of multiple access networks would enable the client to issue multiple interest packets across multiple access alternatives. From a user experience perspective, this allows the application(s) to take advantage of multipath performance benefits and avoid the need to select a single access option or add a common multi-access termination gateway.



5. *Internet Broadcast / Multicast Services*

The capability to efficiently deliver broadcast/multicast services (especially in a mobile environment) without the need to pre-provision significant resources would offer network operators a new opportunity. This application could support a range of applications, including live events, viral videos, public services, and potentially public safety needs.

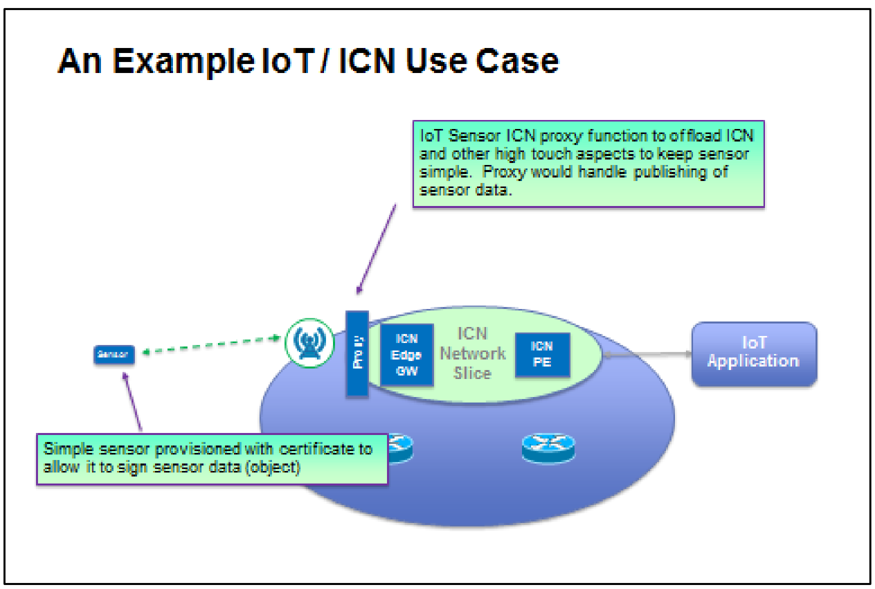
This application is enabled by the concept of a blind object cache at the edge of the network, logically at an ICN edge gateway. A blind object cache is essentially a secondary (localized) server that stores content from a content provider but operates under a secure and authorized relationship between the content originator, the client (browser), and the secondary server hosting the blind cache.



6. Object-based Communication Models for IoT Devices

The rapid growth in IoT devices will influence network operators, and those offering IoT solutions to consider more efficient and lower-cost devices that may not rely on traditional IP protocol stacks and IP addressing.

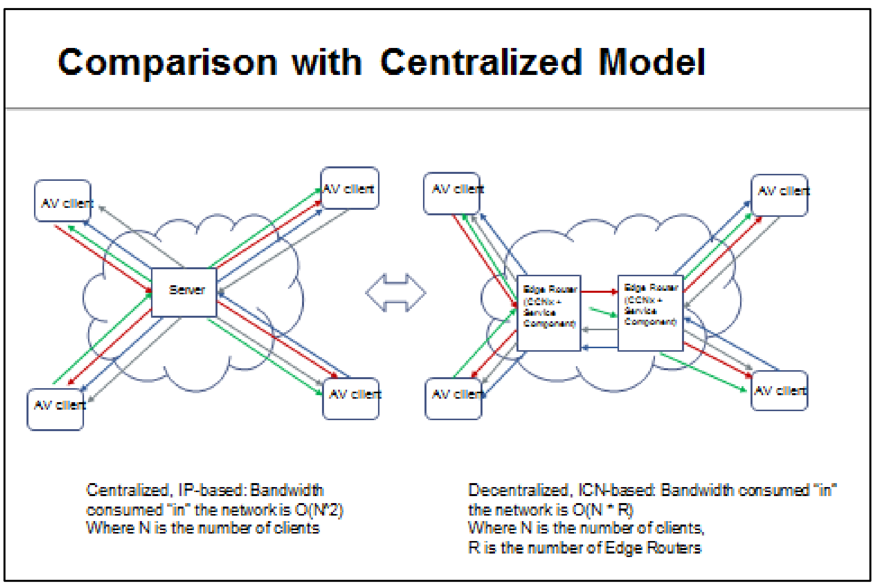
In this use case, an IoT sensor is provisioned with a certificate-enabled data object capability. An ICN network slice is utilized, which includes an IoT sensor and ICN proxy function to handle publishing of sensor data through the network to the associated IoT application. The goal is to use ICN network slices and less complex/lower cost IoT sensors to promote future IoT applications and market penetration.



7. Demonstration of ICN-based A/V Conferencing

One of the early demonstrable applications of ICN is A/V Conferencing using ICN Service-Enabled Routers, which could offer potential for new business models for network operators. This application utilizes caching and aggregation at the edge and supports context-aware networking. This example also takes advantage of service and network virtualization and can be extended to 5G network slicing in the future.

In this application, A/V conferencing services can be tailored to locality and user context (including mobility and social parameters) to provide a richer user experience. From a network perspective, service-centric compute, storage, and bandwidth scaling using virtualization can help to minimize latency/jitter and avoid backbone congestion (which is a challenge in centralized server conferencing architectures).



Preliminary Findings and Next Steps

As research, development and preliminary standards work on content naming solutions is progressing across the industry, ATIS has undertaken this assessment of the "Evolution to Content Optimized Networks" to provide guidance and actionable next steps. One of the key objectives of this analysis is to identify early deployment opportunities and to offer guidance on an initial set of use cases where content-naming approaches can benefit network providers and the broader content industry.

The following is a list of **Key Findings** associated with this first stage of assessment:

1. *Drivers*: An assessment of the future content environment suggests there are significant strategic opportunities for implementing content-naming solutions. Key drivers will be 5G, IoT, growth of edge content, desire for in-network caching, and rapid growth in mobility market.

2. *Deployment*: Target deployment opportunities include early use cases supporting video, IoT, and applications leveraging multipath delivery. Reduction in IoT operational and network complexity is a key goal. Incremental deployments (i.e., ICN over IP) can lead to wider-scale deployments.

3. *Network Evolution*: IP networks are conducive to eCON evolution and the industry will continue to assess the benefits and feasibility of both incremental and disruptive pathways. At a business level, network operators would be aided by an assessment of *demonstrated value over evolutions of IP networking and IP point solutions*.

4. *Challenges*: From an architectural perspective, challenges still exist in reconciling multiple approaches (e.g., CCNx and NDN) and converging on other technical areas such as naming structure, security and trust model, and content caching parameters. Cross-industry collaboration will be a key to success.

5. *Content Ecosystem*: An evolution to content naming impacts the entire ecosystem around content consumption, distribution, and production. Content owners and distributors must recognize the benefits of content-naming solutions and support object-based security model.

6. *Standards*: Industry must progress from research protocols to standards. 5G network slicing is an example of the potential for integrating ICN-based functions into the broader work around 5G and next generation networks, providing an evolution path from current IP solutions and overlays to ICN-based solutions.

In order to promote further assessment of content optimized networks and offer the industry valuable guidance on evolutionary paths, deployment triggers, and business value, ATIS has identified the following **Next Steps**:

1. As a next stage activity, ATIS will extend this assessment to the development of an *eCON Deployment Readiness Report* that will explore deployment-level questions and address network efficiency benefits and deployment triggers. A key aspect of this work will be a use case focused "incremental value assessment" of ICN-based solutions in comparison to IP-based solutions.

2. ATIS will consider a related initiative that explores *Object-based Naming Alternatives* focused on the IoT market – where registries and/or simpler naming structures could promote adoption and deployment.

3. Given the importance of trust and security to the adoption of ICN-based solutions, ATIS will cooperate with the industry and other industry groups to progress the definition of an object-based *Trust and Security Model* that meets the requirements of the future content ecosystem.

4. ATIS will take on a key role in *promoting cross-industry collaboration* between the content-naming development sphere (largely driven by Future of the Internet requirements thus far) and the 5G and IoT network-centric standards activities. This includes research, standards, and concept testing.

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