CONTENT-CENTRIC NETWORKING:
PARC's Strategy for Pioneering a Self-Organizing Network That Meets Information Needs

OVERVIEW
Content-centric networking is an innovative approach to networking that simplifies network use, improves performance and security, and enables a seamless, ubiquitous experience.

Content-centric networks enable the content itself to migrate where it is needed. In an interconnected world where people access digital information via continually shifting modes – moving from location to location, using multiple mobile devices, connecting through diverse networks – a content-centric approach allows them to access relevant, self-organizing information without cumbersome plumbing (i.e., firewalls, VPNs, and ad hoc synchronization protocols). The network can meet specific information needs with available resources, operating within appropriate administrative, performance, and security constraints.

This new approach enables network users to send and receive the right information, at the right place, at the right time – by any means available and regardless of underlying technology.

THE PROBLEMS: Isolation, Disconnection, and Frustration

As Internet “inhabitants,” we virtually live on isolated islands of connectivity, with our digital resources spread across firewalled computers, volatile VPN setups, unstable wireless domains, and floating gadgets such as laptops, PDAs, and cell phones. A task that should be simple – for example, retrieving an event reminder plus driving directions from an office e-mail account while en route in a car – actually requires time-consuming and cumbersome manual configuration.

Enterprises face similar issues on a vast scale. Critical information resources about customer needs, transactions, operating budgets, and process flows no longer reside in centrally managed databases, but in remote data centers. Yet when enterprises attempt to mine their massive, unstructured, and distributed data collections, they spend more time setting up, configuring, and connecting to their networks than they spend analyzing information – time that could have been spent gaining useful insights.

At PARC, we feel that synchronizing and accessing information shouldn’t have to be such a difficult task.

THE SHIFTING LANDSCAPE: Moving from Phone Calls to Cocktails

PARC attributes many of these problems to limitations in underlying networking architectures, which are based on obsolete assumptions. Packet-based protocols for delivering data across networks were developed in the 1970s, when people had no choice but to:

• connect to homogenous, static networks at the same time;
• use a single computer mainframe system that often was shared among multiple users; and
• access limited amounts of information.

As a result, the Internet protocols (IP) which are still in use today send data in chunks (as identified by a globally known, topologically stable, unique IP address) from source to destination – regardless of the information contained within them.

It’s ironic that the success of these outdated network protocols has created a new information world, and posed a new problem: everything seems to be – or wants to be – connected to everything else. In today’s networking environment, people can:

• connect to diverse, dynamic networks at various times;
• use multiple, often mobile devices; and
• access ever-growing amounts of digital information.
Considering the proliferation of wireless and peer-to-peer networks, multicast, broadcast, voice over IP (VoIP), ubiquitous applications, and the advent of context-aware computing, the time is ripe for a fundamentally new approach to networking.

The network of today is different from yesterday’s: Internet communication has moved from point-to-point conversations between hosts, to point-to-multiparty or multiparty-to-multiparty information dissemination. It’s the difference between setting up a phone call between two friends, and hosting a cocktail party.

How does this difference relate to underlying network architecture? You can’t use a telephone to host a cocktail party – where people engage in multiple conversations, move around, eavesdrop on conversations, and ask nearby guests for information. Under current networking assumptions, information processing and content-related work happen only at the ends of the network – as in a phone call between two individuals. Yet sending information based solely on its end-to-end location doesn’t allow the network to maximize available resources and optimize performance based on the nuanced interactions and information inside it.

Here’s an example: during a recent Olympic games broadcast, a major TV station server was overwhelmed by simultaneous requests for a video URL that captured a critical game moment. Since the router was unaware of the content (i.e., it didn’t know that the same information was being requested by many different destination nodes), it choked by responding individually to each of 5,000+ requests. Had the router known about the content it was sending, it could have efficiently handled the requests (e.g., via broadcast, flooding, etc.).

THE SOLUTION: From Abstract to Meaningful

What would happen if the TV station’s network could distribute information more efficiently by disseminating content – instead of blindly conducting abstract, location-based conversations between source and destination nodes?

Enter content-centric networking.

Also known as “dissemination networking,” content-centric networking shifts the focus from transmitting data by geographic location, to disseminating it via named content.

PARC’s “context-aware, content-centric” approach to networking enables named content to migrate wherever it’s needed. Meanwhile, network nodes – empowered with more storage and processing power than ever – can exploit the context of the interaction. The named content doesn’t have to reside anywhere in particular, eliminating the need for global topologies. With only a name, any device that hears the data request can respond to it. Using any means available – IP, VPN tunnels, Zeroconf techniques, multicast, proxies, opportunistic transportation such as planes, and so on – the network acquires the requested content and delivers it to the user. The Network Itself Doesn’t Matter.

Content-centric networking won’t overhaul existing network pipelines, but it will use them to restructure the way networks manage resources and distribute information. Several ad hoc solutions – such as Akamai Content Delivery Networks, Bittorrent digital content delivery platforms, DNS Servers and digital hash tables, and Publish/Subscribe messaging systems – exist at the network layer as a “de facto content layer” to bridge the gap between networks, content, and users. These patchwork solutions confirm the need for an underlying architectural solution such as PARC’s content-centric networking.

THE RESULTS: Enabling the Human Network

Content-centric networking will drastically simplify people’s lives, and support a host of new and emerging applications. The network can communicate on a person’s behalf from inside the network, by focusing on what he or she actually wants instead of meaningless abstractions. A person can also express intent to the network – for example, a parent working from home can instruct his home network to prioritize work-related e-mail over his teenager’s social web traffic.

As the network self-organizes, content-centric networking eliminates the need for time-consuming and cumbersome plumbing. Content will move where it needs to, in the most efficient manner possible. Let’s say a person riding on a bus wants to retrieve a New York Times article on her laptop; the network can retrieve the content through her neighbor’s cell phone instead of manually connecting to a more remote newspaper server location.

Content-centric networking facilitates mobility, autonomous sensing, and wireless access, sometimes by using simple and quick local protocols. Under current networking architectures, you’re either entirely “in” or “out” of the network.

No connection? No network. Content-centric networking, however, enables your information and the network to always be available – even in locations with limited network resources (including developing countries and demand-response situations).
Content-centric networking enables communication to happen with anything, anytime, anywhere.

Content-centric networking could eliminate security problems such as spam, phishing, pharming, and so on, because it secures the content instead of the channel.

Under current network-security approaches, even the most secure mail server will send spam because the network doesn’t know what content it’s moving. Using content-centric networking, integrity and trust are properties of the data — not of the corruptible way in which it arrives — so content can be validated upon arrival. Content-centric networking addresses security at an architectural level.

Content-centric networking dramatically improves network performance on a broad scale by:

- improving efficiency by at least three orders of magnitude;
- reducing congestion and latency because the same or irrelevant information isn’t repeatedly sent through the same pipelines;
- increasing reliability because information is delivered using any available medium; and
- reducing set-up time, manual configuration, and operating costs.

PARC’s VISION: Shoot the Messenger, Not the Message

Imagine that you can receive or send any package, without having to go to a post office or address the envelope. You simply hand it to anyone (it doesn’t even have to be a certified delivery person), perhaps a handsome stranger nearby. The package would pass to your intended recipient by any means available — plane, train, paper airplane, pigeon — as quickly and efficiently as possible. When your recipient receives the package — on whatever location, device, or network she’s using at that moment — the authenticity of the package’s contents could be verified by an embedded code reader or similar technique. This scenario may sound like something you’d find only in J.K. Rowling’s Harry Potter world of owls and magic, but it’s analogous to what the network does under content-centric networking.

ABOUT PARC: Transforming the Vision into Reality

To achieve our goals, PARC draws on a rich legacy of network innovation, coupled with diverse application experience and cross-disciplinary expertise.

PARC collaborates with sponsors and clients to discover novel business concepts and to transform how enterprises deliver value to customers. PARC’s researchers — physical, computer, biological, and social scientists — take an agile, cross-disciplinary approach to innovation. Thirty years of experience creating transformative technologies have given PARC the vision and the practical expertise to convert groundbreaking scientific findings into practical prototypes that solve real needs and create new opportunities. Founded in 1970 as part of Xerox Research, then incorporated in 2002 as an independent research business, PARC is celebrated for such innovations as laser printing, distributed computing and Ethernet, the graphical user interface, object-oriented programming, and ubiquitous computing. PARC is a wholly owned subsidiary of Xerox Corporation.

Interested in learning more?

Media contact: Linda Jacobson, Manager, Marketing & Communications, ljacobson@parc.com or 650-812-4035

Business contact: David Weinerth, Director of Business Development, Computing Science Laboratory, weinerth@parc.com or 650-812-4428