CONVINcE: Greening of Video Distribution Networks

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Outline

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- Cognitive Network Operation and Management
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Blekinge Institute of Technology

- Blekinge Institute of Technology (BTH) is located in Karlskrona, the region of Blekinge, most south-east part of Sweden

  - [http://www.bth.se](http://www.bth.se)
  - [http://www.blekinge.se](http://www.blekinge.se)
Blekinge Institute of Technology (cont)

- BTH has three Faculties
  - Faculty of Computing (COM)
  - Faculty of Engineering (ENG)
  - Faculty of Health Science (HAL)

- BTH is part of Telecom City
  - http://www.telecomcity.org
COM has five research laboratories

- Department of Computer Science and Engineering (DIDD)
- Department of Creative Technologies (DIKR)
- Department of Technologies and Aesthetics (DITE)
- Department of Software Engineering (DIPT)
- Department of Communication Systems (DIKO)
Department of Communication Systems

- Architectural concepts and implementations of communication and distributed systems
- Demands for high capacity, reliability, security and QoS/QoE
- The research covers the whole TCP/IP protocol stack
- Hardware as well as software architectures are considered in our research
- Use of traffic measurements, modeling and analysis
- Recent research: cognitive radio networks, mobile cloud computing, network virtualization, green cellular networks, QoE
CONVINcE: Greening of IP-Based Video Distribution Networks
European Telecommunications Standards Institute (ETSI) indicate that the total contribution of ICT to global Green-House Gases (GHG), including carbon dioxide (CO₂), is today in the range of 2% - 2.5% of total emissions, with about 0.2% attributed to mobile telecom and 0.3% attributed to fixed telecom; these figures may grow as ICT become more widely deployed.

However, ICT also contributes to reductions in emissions in different sectors of the economy, e.g., smart buildings, smart logistics, smart grids, smart motor systems; by this, it is expected that ICT will contribute to a reduction of global emissions by as much as 15% by 2020.

Evolution of energy consumption for different segments of an operator’s network.

Source Ref 1
EU is aiming for a 20% cut in Europe’s annual primary energy consumption by 2020.

The Commission has suggested several measures to increase the efficiency at all stages in the energy chain: generation, transportation, distribution and consumption.

The measures mainly focus on the public transport and building sectors where the potential for energy savings is greatest.

The Commission is however recognizing the enabling role of the ICT sector as well.

The Commission is aware that the ICT sector itself is responsible for rapidly growing carbon emissions and therefore they must be kept to a minimum.

Source Ref 2, 3
CONVINcE – Consumption Optimization in Video Networks

Research project labeled by the EUREKA Celtic-Plus for funding approval in five European countries: France, Sweden, Finland, Romania and Turkey; a number of 19 industrial and academic partners from these countries are participating; project leader is Thomson Video Networks in France.

Today, the project has been funded by the Public Authorities (PAs) in three participating countries. Turkey and Romania are still waiting for decisions.

The project runs in the time period September 2014 – February 2017.

Project goal: greening of IP-based video distribution networks with an e2e approach, from the Head Ends to terminals, also embracing the CDN and access and core networks.

Project focus: architectures, hardware and software designs, protocols and basic technologies in devices.

Focus is also laid on software best practices and eco-design as well as on power and QoE measurements.

Other important goal is to prove demonstrators and to push the expected results to standardization bodies.

Project information is available at https://bscw.celticplus.eu/pub/bscw.cgi/d985/CONVINcE-start_lq.pdf.

Source Ref 5
Greening is about minimizing energy consumption, maximizing energy use efficiency and using, whenever possible, renewable energy sources; also, use of eco-friendly components and consumables.

Source Ref 5
Project Goals

To study the power consumption of video delivery systems and to identify potential savings

To develop solutions to reduce the power consumption

To demonstrate the efficiency of the suggested solutions

To push these solutions to standardization bodies to allow wide commercial deployments
Project Structure

Figure 8 - Project structure
Video over IP Distribution Systems

Chain model: acquisition → production and packaging → primary and secondary distribution

Source Ref 4
Main Elements Network Architecture

- Architecture of type Cognitive (Wireless) Network over Multiple Operators (CWNMO), also known as Cognitive (Wireless) Cloud
- Developed and implemented on top of 4G/5G cellular infrastructure
- Three categories of network architecture are considered for study: non-cloud; edge-cloud; SDN/NFV
- Content distribution (CDN) are deployed on top of network architecture
- Video networks are deployed on top of CDN networks to provide the expected service and experience, security, interactivity and reliability
- Cognitive network operation and management (CNOM)
- Green cloud and green operation
High Level Architecture

- High-Level (application) elements (Content Distribution) also including head end and terminals
- Low-level (network) elements (Radio Access Networks, Wired Access Networks, Wide Area Networks)

Control elements (network virtualization, cloud, data centers, cognitive network operation and management)

Source Ref 5
Project Development

1. Decide on the particular scenarios and appropriate architectures
2. Determine the parameters relevant for low-level elements
3. Determine the functions relevant for high-level elements, which are dependent on the low-level parameters
4. Estimate these functions for the particular scenarios, by using measurements, simulations and theoretical studies
5. Implement the functions in the control elements for the particular architecture and scenario
6. Determine the best trade-off performance vs energy saving for the whole service chain
Green networking refers to environmentally sustainable networking and regards the study and practice of efficient designing, using and disposing of networking and communication systems with minimal or no impact on environment; it includes aspects of environmental sustainability, improved system performance and use, economics of energy efficiency and total cost of ownership.

Sustainability refers to green physical attributes, business processes, ethics, values and social justice.

Traditional design is based on oversizing (to handle traffic peaks) and redundancy (to solve failure situations); both principles are diametrically opposed to the principles of green networking.

The goal is to reduce power consumption while maintaining network performance and availability.

Difficulties in determination of the four fundamental key trade-offs of energy efficiency with network performance, in terms of deployment efficiency (balancing deployment cost), spectrum efficiency (balancing achievable rate), bandwidth (balancing the bandwidth utilized) and delay (balancing average e2e service delay).

Triple bottom line: a calculation of financial, environmental and social performance, also referred to as “profits, planet and people”; this is in contrast with the traditional business bottom line, which is focused on profits only.
Green Networking (cont)

- Several important strategies for green networking
  - Proportional computing – adapt devices processing speeds and link speeds to the existing load
  - Traffic consolidation – concentrate traffic and turn off idle resources
  - Virtualization – consolidate physical resources and increase their utilization rate
  - Adaptive Link Rate – adapt link speed to load
  - Proxying – maintain network presence of turned-off devices
  - Energy-aware routing – consolidate traffic and prioritize routes with energy efficient devices
  - Energy-aware TCP - TCP sleep facility with sleep option in the TCP header
  - SNMP extension – expose devices power state, power management facilities and current settings, monitor energy consumption and generate statistics
  - Physical layer - use of optical fibers, static improvements in interfaces, improvements in cable performance, 802.3az Energy Efficient Ethernet

Source Ref 6, 7
Green Radio Access Networks

- Focus on 4G/5G
- Multi-dimensional aspects related to huge increase in demand for mobile data traffic
- Continuous increase of energy consumption related to Base Stations (BSs)
- Complex, multi-dimensional problem
- The appearance of heterogeneous networks further complicates the problem
- Several solutions exist today, each of them with advantages and limitations; these solutions are acting at different levels: technology, BS, cell site, network
- Main greening elements: metrics (facility-, equipment-, network-level), Base Stations, system design, cloud RAN, (heterogeneous) network planning
Important research questions

- Energy-Efficiency (EE) metrics for RANs that are neutral and independent of other metrics like spectrum efficiency and deployment efficiency

- Improve the efficiency of BSs, as measured by the RF output power referred to the total AC input power; most efficient solutions, single BS based or (heterogeneous) or group BSs based?

- Develop and deploy efficient sleep modes for BSs; what is the most efficient Power Amplifier (PA) based method to improve the efficiency and to save energy in a radio BS: time-based domain (shut down the PA when there is no traffic in the downlink)? Frequency-domain approach (aka spectrum balancing)? Spatial-domain approach (reduce the number of antennas)? Is it possible to develop combined solutions?

- Develop efficient solutions for heterogeneous networks; maximize spectrum efficiency; ensure wireless access universality and resilience

- Use of techniques from Dynamic Spectrum Access (DSA) and Cognitive Radio Networks (CRNs)

- Use of multi-dimensional, multi-hop green routing to save energy
Green Wide Area Network

- General observation: the existing policies used today in WANs (overprovisioning and redundancy policies) are totally in opposition with green networking policies; they are focused on QoS support only.

- Main problem is huge complexity due to large numbers of schemes, policies and parameters.

- There are four main directions to follow for the greening of WAN:
  - Adaptive link rate (e.g., sleeping mode, reducing the link rate at low traffic)
  - Interface proxying (delegate traffic processing to more energy efficient entities, e.g., cloud)
  - Energy-aware infrastructure (energy-aware routing, sleeping, dynamic adaptation)
  - Energy-aware software and applications (adaptation of OS and applications)

- Important elements: determination of network power consumption model, power-aware routing mechanisms, determination of appropriated green metrics to capture the greening properties of routing in wide-area networks.
Cloud Network Virtualization

- Set of mechanisms used to let more services operate on a given set of heterogeneous resources, so-called cloud

- Positive effects like more efficient service delivery, reduced resource costs, reduced energy

- Other benefits: reduced CapEx and OpEx, accelerated Time-to-Market, provide agility and flexibility
Today, the move is towards Software Defined Networking (architectural framework for creating intelligent programmable networks) combined with Network Function Virtualization, which enables network functions traditionally tied to hardware appliances to run on cloud infrastructure in a DC.

- Functional elements in a virtualization platform
  - Heterogeneous wireless access networks
  - Integrated resource management, both wired and wireless networks
  - Data Center (DC), for management purposes

- Particular difficulties
  - Abstraction of heterogeneous networks
  - Programmability
  - Isolation of resources
  - Development of green virtualization platforms

Source Ref 10
Today, wireless operators massively deploy LTE and HetNet infrastructures based on the increasing demands for high-speed mobile broadband connectivity; an important consequence is in form of increasing global wireless CapEx.

SDN/NFV eliminate the need of expensive proprietary hardware platforms; reduced CapEx burden on wireless carriers is obtained, also significantly slashed OpEx due to reduced physical space and power consumption; Total Cost of Ownership (TCO) is lowered as well.

The wireless carriers are today aggressively adopting SDN/NFV, with the goal of integration and cloud-based control across several areas including RAN, mobile core, backhaul and home environment.

Requirements on interoperability, isolation, aggregation, performance trade-off, management and orchestration, scalability.

Source Ref 9, 10
CDN is basically a ring of caches located near access providers to ensure better and cheaper content experience.

Greening of CDN and DC without influencing the performance at terminals is extremely complex; demands for integration of mobility and backhaul considerations on what cache to draw information from and for dynamic switching of cache locations when the user moves between cells or operators.

Three elements in CDN architecture: content type; CDN type; services.

Important elements for energy saving are CDN type (public CDN, enterprise CDN, edge services, P2P file sharing), virtualization and centralized storage, workload consolidation and allocation policies.

Other important elements are the cloud-based services and the developments imposed by 3GPP (Release 12 LTE Advanced).

Important research questions are on accelerated content delivery in mobile networks/mobile cloud accelerator and virtualization of Edge Data Centers (EDCs) with virtualized (parts of) hardware.

Source Ref 11
Data Centers

- There are three parts in a Data Center
  - DC IT infrastructure
    - Servers (rack-mounted servers; blade servers; containers)
    - Networking
    - Storage
    - IT platform innovation (server farm; grid computing; service orientation; virtualization; cloud computing)
  - DC Facility infrastructure
    - Power system (AC vs DC)
    - Cooling system
    - Facility infrastructure management
  - IT Infrastructure management
    - Server power
    - Consolidation
    - Virtualization

- A high density Data Center (DC) may have thousands of racks; the heat dissipation from a rack may range from 10-30 kW; the result is that, e.g., for a DC with 1000 racks, over 30,000 square feet (ft²) requires 10-30 MW of power; bigger DCs like, e.g., a 100,000 ft² DC of the future may need 50-125 MW power!
- Further, the energy required to dissipate this heat will be an additional 20-50 MW
- The consequence is that the cost may become very high, e.g., $44 million/year (at $100/MWh) to power DC servers and $18 million/year for cooling infrastructure for DC
- Another consequence is that there is need for energy optimization program to manage electricity demands and associated carbon emissions, protect vital data and computing functions, reduce risk of power outages, etc

Source Ref 12
Power consumption is the main operational cost of Data Centers. Typically, the cost for cooling and heat removal in DCs is twice the one of IT. Power Usage Effectiveness (PUE) is the ratio Total_Facility_Power / IT_Equipment_Power. Traditional PUE values are of 1.5 to 3. Examples of current values: Google PUE is 1.14 (2011); Facebook PUE is 1.07 (2013, also including the Luleå DCs).

Facebook has, e.g., decided to build up their first DC outside the USA, and placed in Luleå, north of Sweden; reasons: cold climate (gives cost savings), very good infrastructure (no major power outage in the last 40 years), stability; the so-called Rapid Deployment DC concept is used (similar to IKEA’s concept).

DC IT infrastructure strategies focus on improved cooling and better power distribution. The most important techniques are DC cooling strategies, Improved power distribution, Overall Best Practices, Blade Technologies, Other IT greening techniques.

DC cooling strategies:
- Computer Room Air Conditioner (CRAC)
- Computer Room Air Handler (CRAH)
- Humidifier
- Chiller

A set of Best Practices for DC cooling has been suggested by the Dept of Energy (DoE) in the USA.
Three generations Data Centers built up by Facebook in Luleå, Sweden (2012, 2014, ?) Very good values obtained for PUE = 1.07; this saves lot of money!
Cognitive Network Operation and Management

- CNOM is about adaptive mapping of user requirements, preferences and context onto the offered services by considering resource assignments, strategies and other policies of the service provider
- CNOM is an extension of 3GPP Self-Organizing Networks (SON) concept to radio access and WANs operation
- CNOM provides elements for efficient increase of resource usage, energy saving, cost-efficient network operation, operation and administration
- Need to develop the delivery-centric paradigm to replace the existing (static, agnostic to location or protocol) content distribution paradigm, which is very complex with the consequence of performance limitation; this paradigm considers the environmental (protocol) variance
- Reconfigurable software suite with three layers is used
- Two categories of software suite: CNOM of access network and CNOM of core network
- There are three CNOM managers
  - Cognitive manager: reconfiguration actions via APIs for virtualization and reconfiguration purposes
  - Wired network manager
  - Wireless network manager
Cognitive Network Operation and Management (cont)

Middleware

- Multi-dimensional knowledge database
- Historical statistics database (only Cloud)
- Decision maker
- Spectrum access and policy
- Green operations and policy
- Multi-cell scheduling and coop communic
- Cloud control and CCC
- Wireless as a Service (WaaS)

Software Defined Radio (SDR)
- LTE
- WiMAX
- WiFi
- ...

virtual Base Station
- LTE
- WiMAX
- WiFi
- ...

IP/MPLS

Software suite for RAN

Source Ref 8
Video services are expected to show huge development in the future and, associated with this, large energy consumption.

Some of the most important research challenges are on the greening of RANs and core networks, network virtualization, greening of content distribution and data centers as well as cognitive network operation and management.

Solving these challenges demands for sustained research and development efforts.

CONVINcE is expected to bring in important contribution to solving these problems.

CONVINcE is further expected to lay the framework for a close research and industrial cooperation among 19 partners in 5 countries.
References


THANK YOU!