Research for Making the Internet and the Grid More Sustainable

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Acknowledgments:
- Colin Perkins
- IRTF Research Group Chairs

IETF
Mission

Make the Internet work better by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet.

[RFC 3935]

Engineering vs. Research

I E T F®

- Quality engineering solution for well-understood problems
- Responding to current needs
- Interoperable standards that enable new products and technology improvements

Engineering vs. Research

- Quality engineering solution for well-understood problems
- Responding to current needs
- Interoperable standards that enable new products and technology improvements

- Longer research issues that relate to the future development of the Internet
- Understanding systems and technologies deeply
- Enabling experiments that inform future engineering work
- Provide a forum for international research collaboration

16 IRTF Research Groups

CFRG
Crypto Forum Research Group

GAIA
Global Access to the Internet for All

NMRG
Network Management

ICCRG
Internet Congestion Control

ICNRG
Information-centric Networking

MAPRG
Measurement and Analysis for Protocols

HRPC
Human Rights Protocol Considerations

PEARG
Privacy Enhancements and Assessments

QIRG
Quantum Internet

RASPRG
Research & Analysis of Standards Processes

PANRG
Path Aware Networking

UFMRG
Usable Formal Methods

DINRG
Decentralised Internet Infrastructure

SUSTAIN
Sustainability and the Internet

T2TRG
Thing-to-Thing

SPACERG
System and Protocol Aspects for Circumstellar Constallations

irtf.org

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Bigger Topics: Architectures & New Paradigms

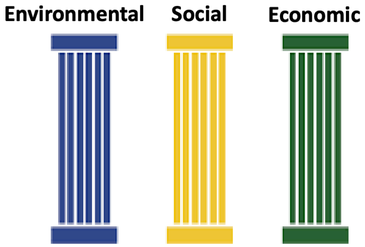
SUSTAIN
Sustainability and the Internet

Long-term research challenges in developing and operating an environmentally, socially and economically sustainable Internet

- **Networking perspective**, mindful of overall impact to systems & services
- Architectural and policy implications
- Focus on the **Sustainability of the Internet** (env, social, econ. **footprint**), & appreciation of the **Internet for Sustainability** (**handprint**)
- **Multidisciplinary, systems perspective** with lifecycle and supply chain considerations

Sustainability Defined

"Meet the needs of the present without compromising the ability of future generations to meet their own needs."



SUSTAIN Research Opportunities

Potential SUSTAIN Research Directions

- **Sustainable Internet Architecture**
  - Instead of optimizing links and bit-level transmission:
  - ***How should Internet architectures evolve when energy becomes a first-class resource?***
  - Examples
    - feasibililty of energy-aware routing
    - carbon- (or cost) aware services
    - graceful degradation under power constraints

SUSTAIN Research Opportunities

Potential SUSTAIN Research Directions

- **Protocols for Cyber-Physical Sustainability**
  - scalable coordination
  - deterministic operation where necessary
  - uncertainty-aware protocols
  - resilience under partial failures

SUSTAIN Research Opportunities

Impact Opportunities

**Instead of focusing on producing protocols,
SUSTAIN might be a good place to develop the conceptual foundations
that later influence the IETF.**

- **Research**
  - identify open architectural questions
  - build shared terminology
  - evaluate new abstractions
- **Community**
  - Connect networking with energy, climate and sustainability researchers
  - Create common datasets and benchmarks
  - Develop reproducible methodologies
- **Technology Transfer**
  - incubate ideas for future IETF work
  - inform standards bodies
  - provide guidance for sustainable Internet evolution

SUSTAIN Research Opportunities

Bigger Questions

How should Internet architectures evolve to support globally (?) interconnected, sustainability-critical cyber-physical systems?

What can be learned from Internet concepts, principles, and previous mistakes for "packet-based grid" designs?

SUSTAIN Research Opportunities

Can we Internetify the Power Grid?

- **Promising principles**
  - federation and local autonomy
  - open interoperability
  - aggregation and statistical multiplexing
  - evolvability and incremental deployment
  - edge intelligence and graceful degradation

SUSTAIN Research Opportunities

Can we Internetify the Power Grid?

- **Promising principles**
  - federation and local autonomy
  - open interoperability
  - aggregation and statistical multiplexing
  - evolvability and incremental deployment
  - edge intelligence and graceful degradation
- **Dangerous analogies**
  - electrons are not packets
  - grid nodes cannot freely buffer power
  - AC power does not follow selected paths
  - physical flows differ from transactions
  - safety-critical control is not best effort

SUSTAIN Research Opportunities

From “Energy Routing” to Precise Research Questions

- What is being routed: power, flexibility, control intent, or money?
- What corresponds to an endpoint, path, buffer, and autonomous domain?
- Which functions can be decentralized safely?
- What information must cross administrative boundaries?
- What minimal interfaces support interoperability?
- How do we demonstrate actual sustainability and resilience gains?

SUSTAIN Research Opportunities

Proposed SUSTAIN Research Agenda

- Critical taxonomy and state-of-the-art review
- Internet-analogy stress-test methodology
- More joint Internet–energy systems workshop
- Case studies and reproducible benchmarks
- Inter-domain flexibility-service architecture
- Coupled power/communication resilience research

SUSTAIN Research Opportunities

My current thinking after the workshop

The opportunity may not be to rebuild the power grid as a packet network.

It is to identify which Internet principles can help make future energy systems interoperable, federated, evolvable, and resilient – and where power-system physics makes the analogy invalid.

Come Work on the Future of the Internet!

- **Shaping the evolution of the Internet by exploring new concepts, technologies, and application areas**
  - Making significant contributions beyond traditional academic publications
  - Fostering collaborations that develop innovative technologies, prototypes, experimental specifications,
  - **IRTF – the premier global forum for applied networked systems research**

Photos: Colin Perkins