VillageCell: Cost Effective Cellular Connectivity in Rural Areas

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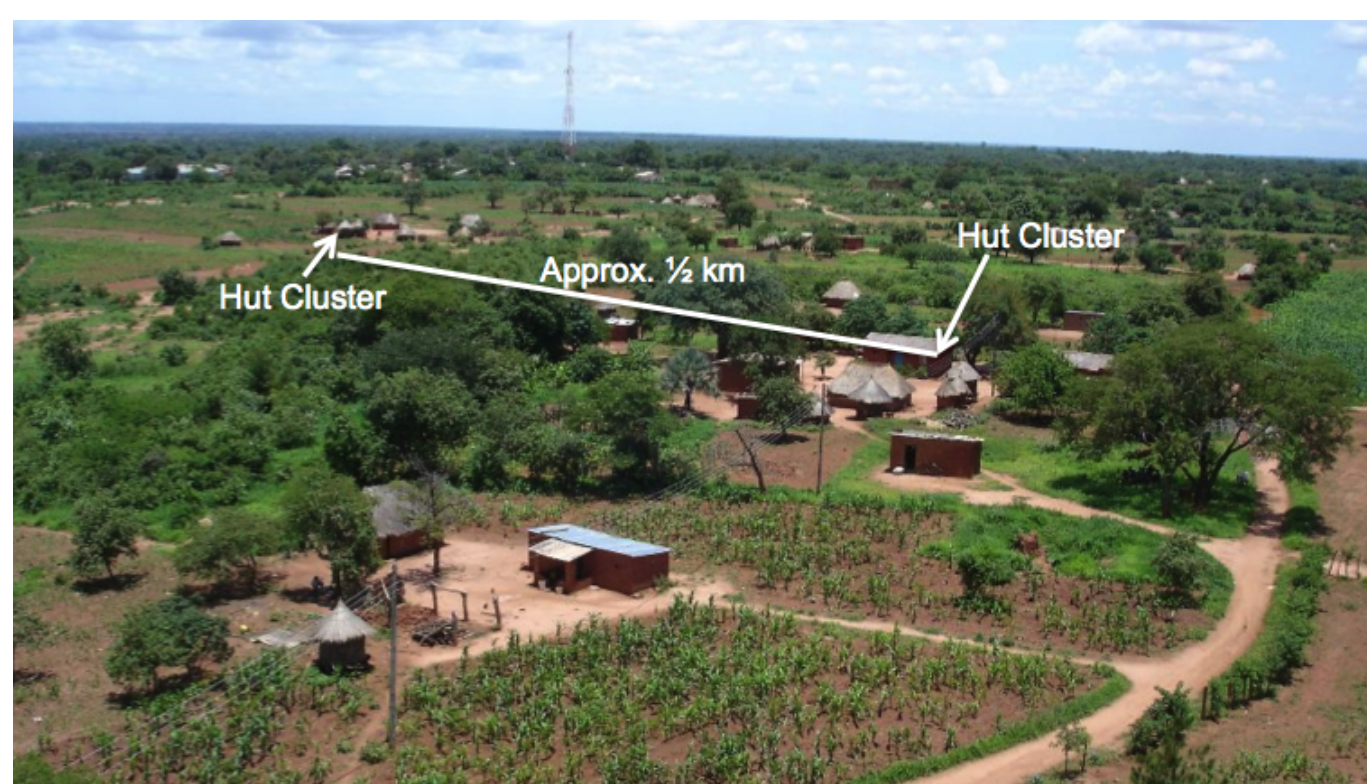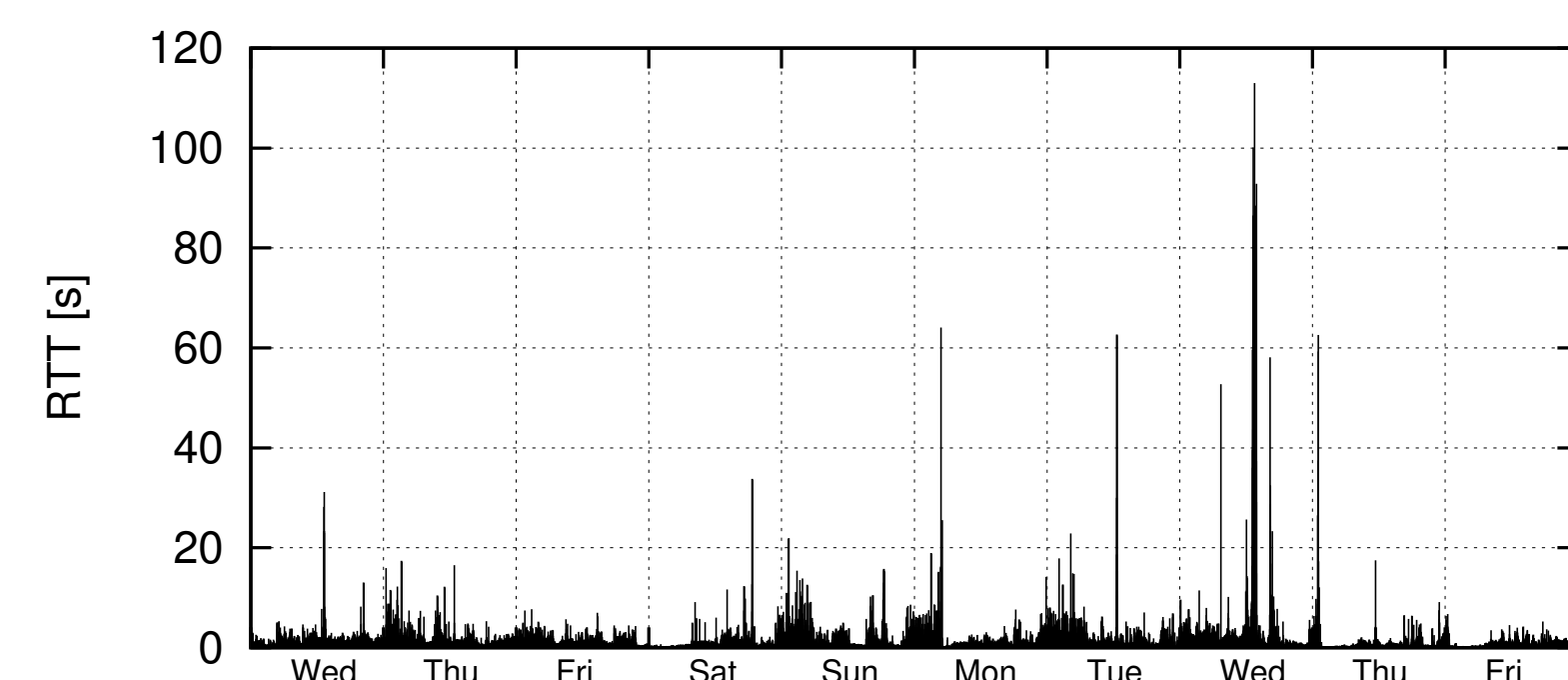
Voice communication in rural Africa

Voice communication is important for economic growth, health care, and political freedom. Mobile handsets are popular in the developing world due to their low cost and robustness.

Voice is used for local communication. We interviewed 37 residents of Macha, Zambia and Dwesa, South Africa about their communication habits. The findings show that 80% of the correspondents use voice for communication within the village (compared to 47% of email locality).
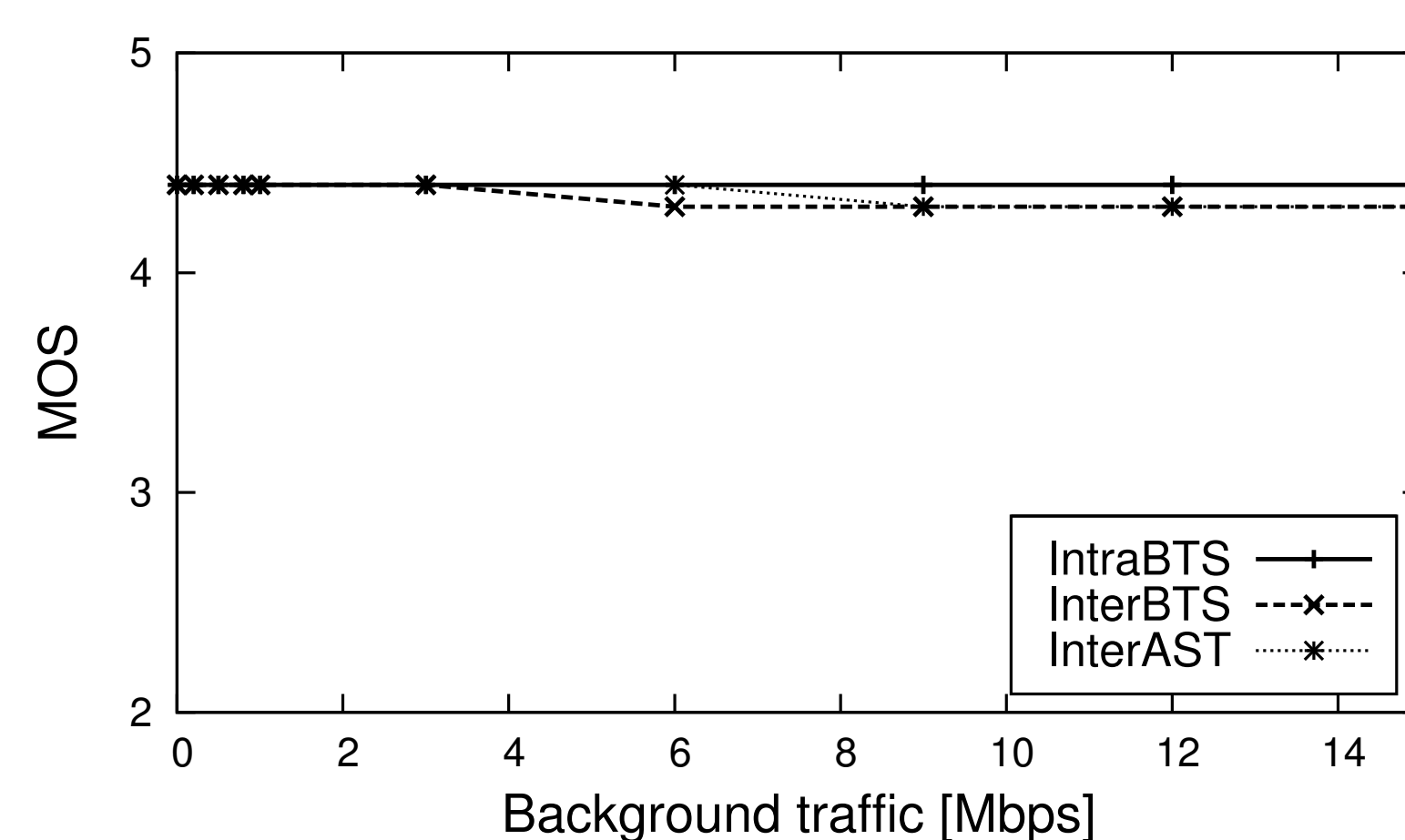
Cellphone base stations are *expensive*, not economically viable for sparsely populated low-income areas.


Voice-over-IP underperforms due to the centralized Internet architecture – a call has to *traverse a slow satellite link twice*, even for a local call, resulting in poor call quality.

VillageCell

VillageCell is a system architecture for localized cell phone communication. VillageCell relies on software defined radios (SDRs) and open-source solutions (OpenBTS and Asterisk) to provide free local and cheap long-distance communication for remote regions. Our architecture is simple and easy to deploy, yet robust and requires no modification to GSM handsets. It is a low-cost alternative to high-end cell phone networks.

VillageCell Architecture Layout

Legend:
- .... GSM link
- —— Local network link
- -·-·- Intra OpenBTS call
- - - - Inter OpenBTS call
- —·—·— Inter Asterisk call
- VillageCell area

- .... GSM
- —— Local network (WiFi)
- -·-·- SIP signaling
- - - - VoIP (RTP)

Call scenarios:

- **IntraBTS**: both parties reside in the same OpenBTS cell.
- **InterBTS**: parties are in different OpenBTS cells, but are controlled by the same Asterisk server.
- **InterAST**: parties are in different OpenBTS cells, and are controlled by different Asterisk servers.

VillageCell components:

- Short-range base station: a PC with an SDR (USRP2) running *OpenBTS* GSM stack implementation; converts G.711 encoded voice to VoIP.
- PBX: a general purpose PC running *Asterisk* call management software; uses SIP signalling protocol.
- Backhaul network: can be any local network, i.e. WiFi, Ethernet or white spaces. VillageCell can be built on top of an existing community network.

VillageCell as a Building Block

VillageCell is an important part of VillageNet. **VillageNet** is a holistic concept that harnesses software-defined radios to connect remote communities. It consists of:

- **VillageLink** - white space links between distant clusters of homes and the Internet gateway.
- **VillageCell** - for a cluster of houses VillageCell provides cell phone coverage.
- **VillageShare**[a] - a traffic localization system, saves gateway satellite bandwidth.
- Spectrum translation among white spaces, GSM and local WiFi hotspots.

[a]D.L. Johnson, V. Pejovic, E. M. Belding and G. van Stam, *VillageShare: Facilitating content generation and sharing in rural networks*. ACM DEV 2012.

Experimental Evaluation

We implemented VillageCell in a lab setting and evaluated it in realistic rural-area network scenarios using traces from the Macha community network. The call quality (measured with the mean opinion score – MOS) is very good with little packet loss, fast setup time and low delay and jitter. The quality remains good even with an increasing number of simultaneous calls.
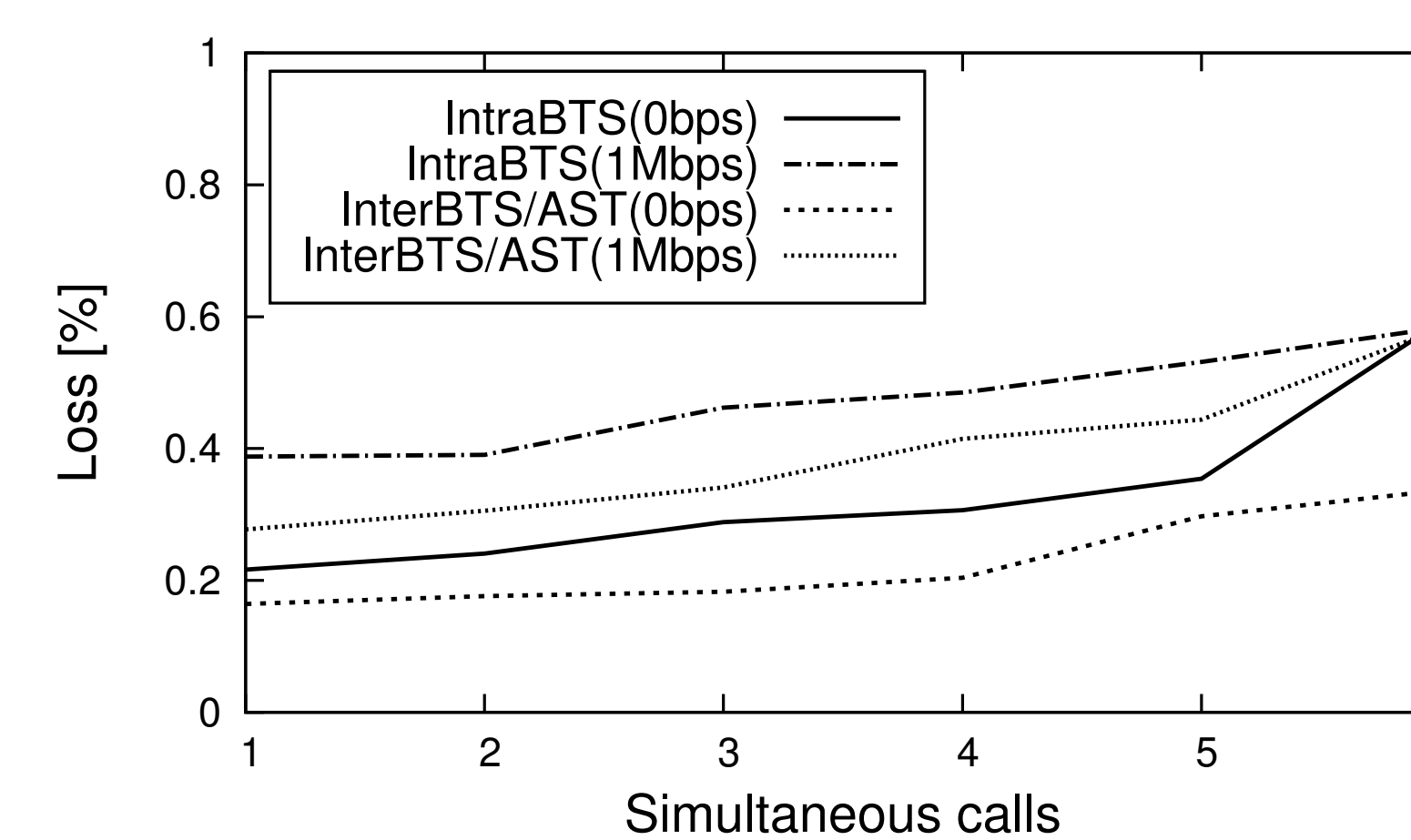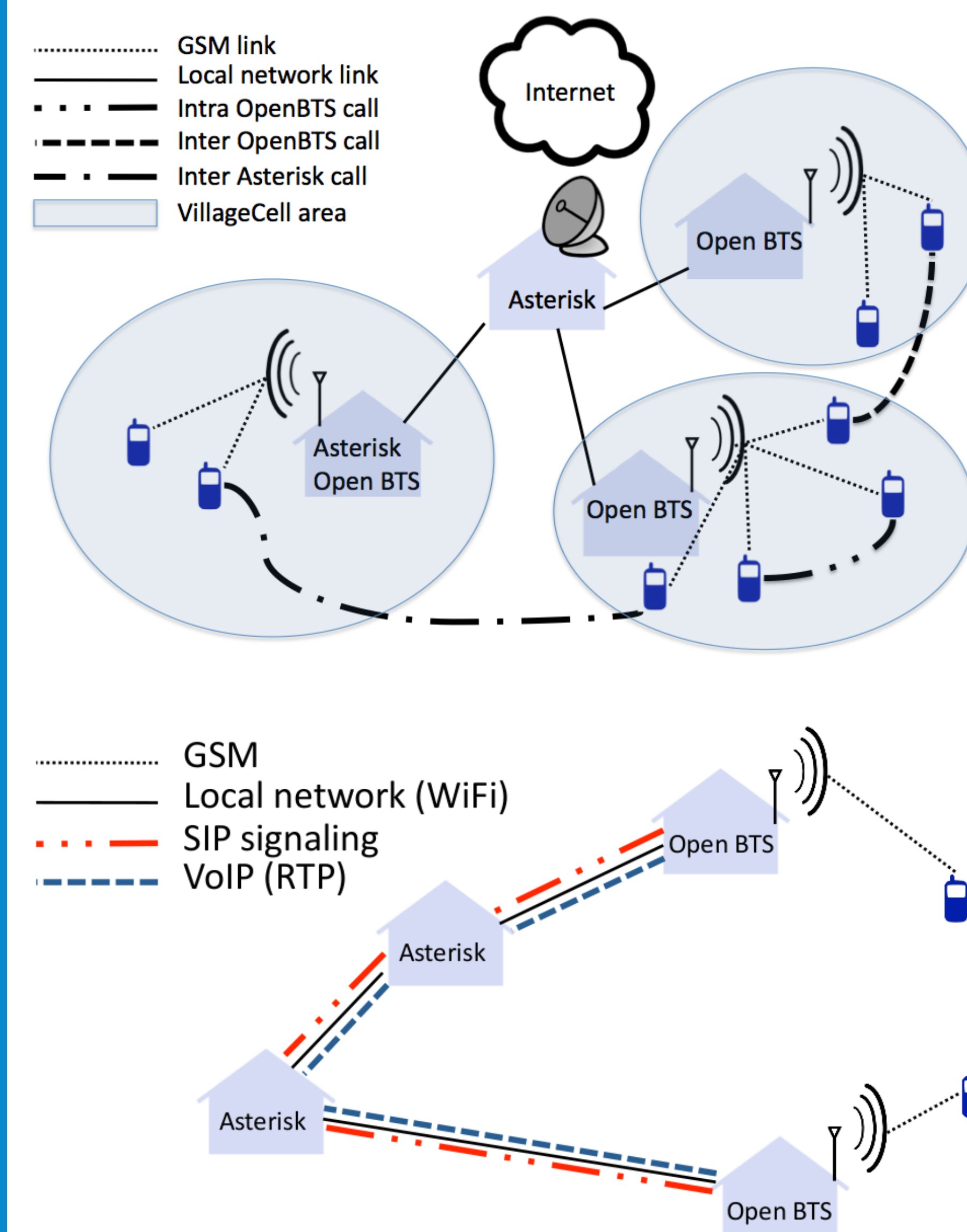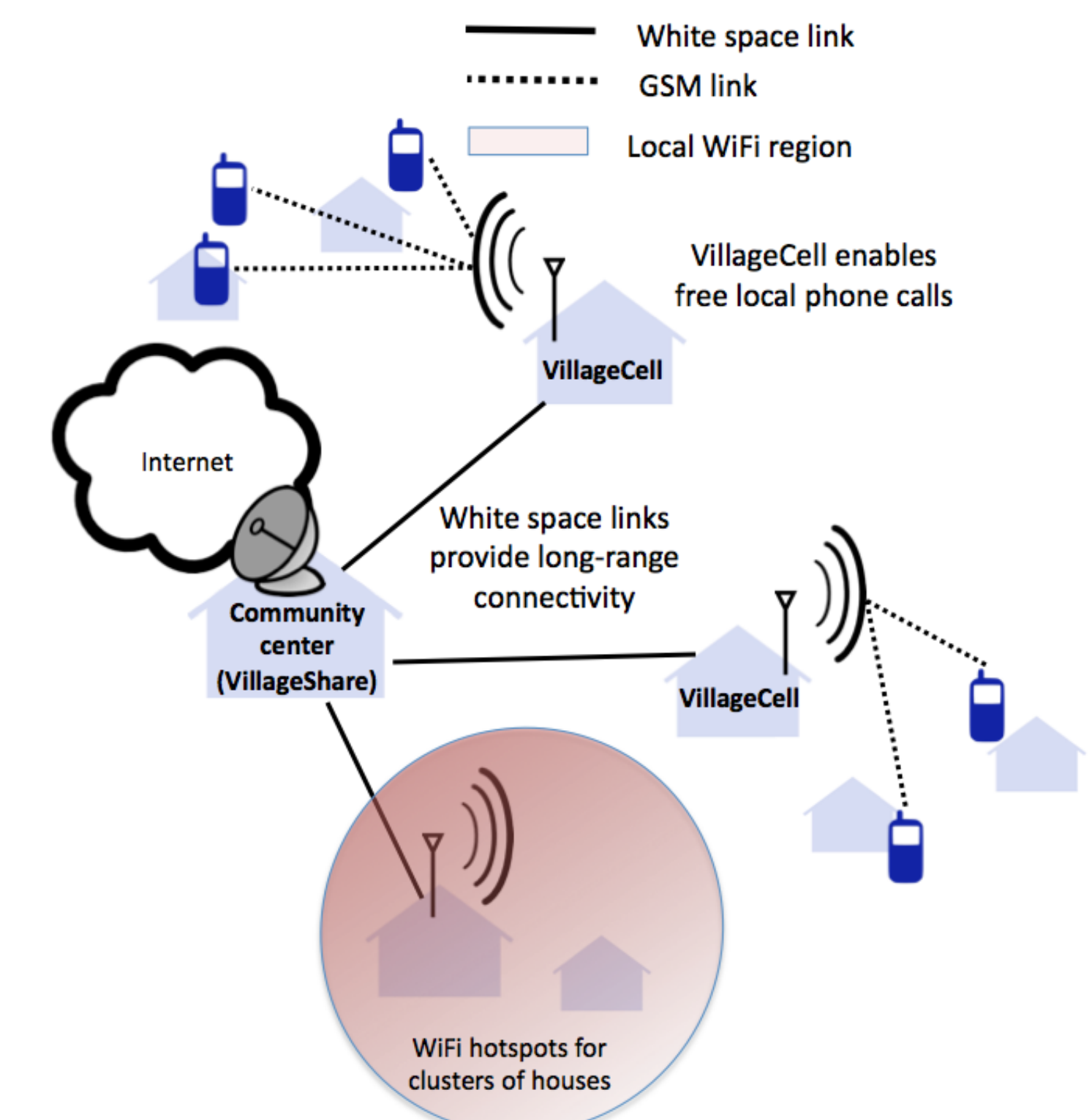

Additional benefits: Through its SMS capability, or data-over-voice solutions, VillageCell can also enable free local data service. VillageCell can be extended so that it provides connectivity to the outside world through its inherent VoIP support. VillageCell requires more than an order of magnitude less power than a commercial cellphone station.