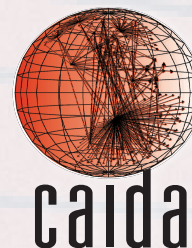


INVESTIGATING THE CAUSES OF CONGESTION ON THE AFRICAN IXP SUBSTRATE

By

Roderick Fanou* (CAIDA/UCSD),
Francisco Valera (UC3M),
Amogh Dhamdhere (CAIDA/UCSD)



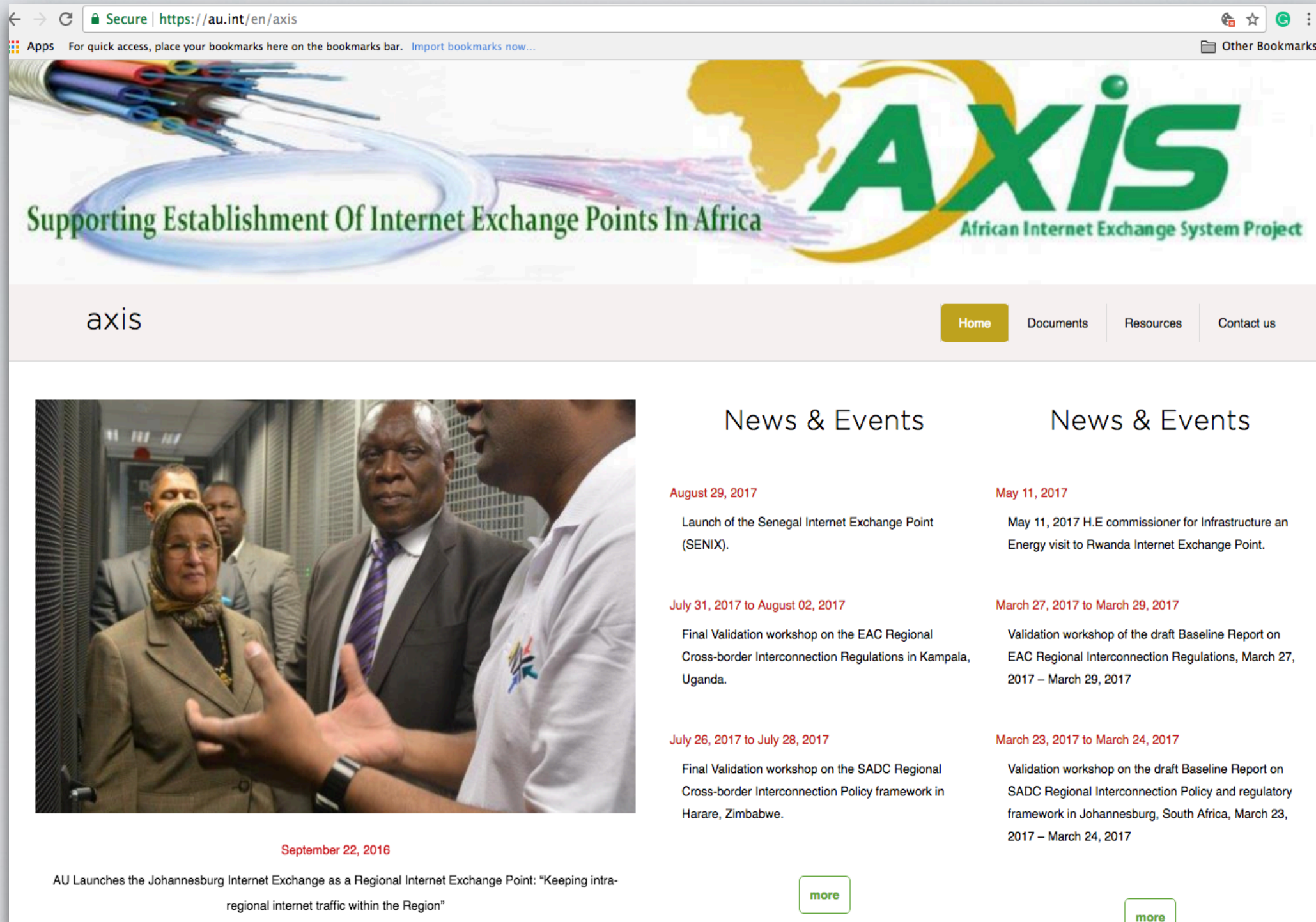
* whose affiliation was then IMDEA Networks/UC3M

DISCLAIMER:

This work [1] was published at the ACM Internet Measurement Conference (IMC) 2017 and the corresponding paper is available at: http://www.caida.org/publications/presentations/2017/investigating_causes_congestion_african_imc/

[1] Fanou, Valera, Dhamdhere. Investigating the Causes of Congestion on the African IXP Substrate. In IMC, 2017.

In the Press



The screenshot shows the website for the African Internet Exchange System Project (AXIS). The header features the project's logo, which includes a map of Africa and the text "Supporting Establishment Of Internet Exchange Points In Africa" and "African Internet Exchange System Project". Below the header is a navigation menu with links for "Home", "Documents", "Resources", and "Contact us". The main content area is divided into two columns, both titled "News & Events".

Left Column News & Events:

- September 22, 2016**
AU Launches the Johannesburg Internet Exchange as a Regional Internet Exchange Point: "Keeping intra-regional internet traffic within the Region"

Right Column News & Events:

- August 29, 2017**
Launch of the Senegal Internet Exchange Point (SENIX).
- July 31, 2017 to August 02, 2017**
Final Validation workshop on the EAC Regional Cross-border Interconnection Regulations in Kampala, Uganda.
- July 26, 2017 to July 28, 2017**
Final Validation workshop on the SADC Regional Cross-border Interconnection Policy framework in Harare, Zimbabwe.
- May 11, 2017**
May 11, 2017 H.E commissioner for Infrastructure and Energy visit to Rwanda Internet Exchange Point.
- March 27, 2017 to March 29, 2017**
Validation workshop of the draft Baseline Report on EAC Regional Interconnection Regulations, March 27, 2017 – March 29, 2017
- March 23, 2017 to March 24, 2017**
Validation workshop on the draft Baseline Report on SADC Regional Interconnection Policy and regulatory framework in Johannesburg, South Africa, March 23, 2017 – March 24, 2017

Each news item has a "more" button below it.

A great push to setup more local IXPs in Africa through the AXIS project (<https://au.int/en/axis>)

In the Press

The screenshot shows a web browser displaying the Af-IX website. The browser's address bar shows the URL <https://www.af-ix.net/ixps-map>. The website header features the Af-IX logo, which consists of a stylized orange and red shape with a black dot and several small stars, followed by the text "The African IXP Association" and "A member of the Internet eXchange Federation". Below the header is a navigation menu with buttons for "Home", "About AFIX", "List of IXPs", "Map of IXPs", "IXP Resources", "ARDA", and "Contact".

The main content area is titled "Map of Internet exchange points in Africa". The text below the title states: "There are currently **38 active IXPs** located in **35 cities** in **29 countries** in Africa. Click any marker for more information. Note that not all marker locations are exact. If you know of an IXP that is not included here, or wish to submit a correction, please [contact us](#). To view this data in a table, [click here](#). To download our full data set in CSV format, [click here](#)." Below this text is a map of Africa with red location markers. A large red arrow points from the text to the map. The map shows markers in various African countries, with some markers containing numbers: 5 in Nigeria, 2 in DR Congo, 3 in Tanzania, 4 in Kenya, and 6 in South Africa. Other countries with markers include Tunisia, Egypt, Sudan, Yemen, Mauritania, Mali, Niger, Chad, Egipto, Arabia, Somalia, Angola, Zambia, Mozambique, Zimbabwe, Botswana, and Madagascar. The map also shows parts of Europe and the Middle East, with labels for countries like España, Italia, Grecia, Turquía, Irak, and Arabia. The map includes a zoom control on the left and a dashed line representing the equator.

On the right side of the page, there are three sections:

- Fiber infrastructure maps**: "Here are two fiber infrastructure maps that may also be of interest:
Submarine fiber cables: <http://www.submarinecablemap.com/>
Terrestrial fiber cables: <http://afterfibre.net/>
- Follow us on Twitter**: "Get the latest news, event announcements, sponsorship opportunities, and AFIX updates by subscribing to our Twitter feed: https://twitter.com/AF_IX
- Join the mailing list**: "We operate two mailing lists for people interested in contacting and/or growing the IXP community. Click here to sign up: <http://af-ix.net/mailman/listinfo/>

In the Press

Secure | <https://au.int/en/axis>

www.af-ix.net/ixps-map

For quick access, place your bookmarks here on the bookmarks bar. [Import bookmarks now...](#)



The African IXP Association

A member of the Internet eXchange Federation

- Home
- About AFIX
- List of IXPs
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Map of Internet exchange points in Africa

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Follow us on Twitter

Get the latest news, event announcements, sponsorship opportunities, and AFIX updates by subscribing to our Twitter feed:
https://twitter.com/AF_IX

Join the mailing list

We operate two mailing lists for people interested in contacting and/or growing the IXP community. Click here to sign up:
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38 active Internet eXchange Points (IXPs) in **35** countries (October 2017)

In the Press

The screenshot shows a web browser window displaying the website of The African IXP Association. The browser's address bar shows the URL <https://www.af-ix.net/ixps-map>. The website header features the Af-IX logo, which consists of a stylized orange and red shape resembling a person or a flame, with the text "Af-IX" below it. To the right of the logo is the main title "The African IXP Association" in a large, bold, blue font, followed by the subtitle "A member of the Internet eXchange Federation" in a smaller, blue font. Below the header is a navigation menu with several buttons: "Home", "About AFIX", "List of IXPs", "Map of IXPs", "IXP Resources", "ARDA", and "Contact". The "Map of IXPs" button is highlighted in red. The main content area is titled "Map of Internet exchange points in Africa" and contains a paragraph of text. To the right of this text is a section titled "Fiber infrastructure maps" with two sub-sections: "Submarine fiber cables" and "Terrestrial fiber cables", each with a corresponding URL. Below the text is a map of Africa showing the locations of 44 active IXPs. The map is a satellite-style map with red pins indicating the locations of the IXPs. The pins are numbered from 1 to 5, with a large red arrow pointing to the number 5. The map also shows the outlines of the African continent and the surrounding countries. The browser's status bar at the bottom shows "Secure" and "https://www.af-ix.net/ixps-map".

Secure | <https://au.int/en/axis>

The African IXP Association | A x

Secure | <https://www.af-ix.net/ixps-map>

For quick access, place your bookmarks here on the bookmarks bar. [Import bookmarks now...](#)

The African IXP Association

A member of the Internet eXchange Federation

[Home](#) [About AFIX](#) [List of IXPs](#) [Map of IXPs](#) [IXP Resources](#) [ARDA](#) [Contact](#)

Map of Internet exchange points in Africa

There are currently **44 active IXPs** located in **40 cities** in **32 countries** in Africa. Click any marker for more information. Note that not all marker locations are exact. If you know of an IXP that is not included here, or wish to submit a correction, please [contact us](#). To view this data in a table, [click here](#). To download our full data set in CSV format, [click here](#).

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The main content area is titled "Map of Internet exchange points in Africa". It contains the following text: "There are currently **44 active IXPs** located in **40 cities** in **32 countries** in Africa. Click any marker for more information. Note that not all marker locations are exact. If you know of an IXP that is not included here, or wish to submit a correction, please [contact us](#). To view this data in a table, [click here](#). To download our full data set in CSV format, [click here](#)."

To the right of the main text, there are sections for "Fiber infrastructure maps" with links for submarine and terrestrial fiber cables, "Follow us on Twitter" with a link to the Twitter feed, and "Join the mailing list" with a link to sign up.

A large red arrow points to a semi-transparent box overlaid on the map of Africa, which contains the text: "44 active IXPs in 32 countries (September 2018)".

In the Press

The screenshot shows the 'African Route-collectors Data Analyzer' (ARDA) web interface. The browser address bar displays the URL: https://arda.af-ix.net/ARP/index.php?module=hors_connexion&action=Test11. The page title is 'African Route-collectors Data Analyzer'. The navigation menu includes 'A.R.D.A.', 'IXP view', 'National view', 'Regional view', and 'Towards ARD'. A dropdown menu is open, listing various IXP options: AIXP (TZ), BINX (BW), BeninIX (BJ), CAIX (EG), CINX (ZA), DINX (ZA), IBIXP (NG), JINX (ZA), KIXP (KE), LIXP (LR), MGIX (MG), MIXP (MW), MOZIX (MZ), MSA-IX (KE), MixP (MU), **NAPAfricaCT (ZA)** (selected), NAPAfricaDB (ZA), NIXP (NG), RINEX (RW), SIXP (GM), SixP (SD), TIX (TZ), TunIXP (TN), UIXP (UG), and WHKIX (NA). The main content area features a bar chart titled 'NUMBER OF VISIBLE Peering ASNs AT AN IXP'. The chart shows the number of peering ASNs over five weeks, with the y-axis labeled 'Number of Peering ASNs' and the x-axis labeled 'Date thresholds'. The legend indicates '# Peering ASNs'. A red text box is overlaid on the chart with the text: 'And their evolution can be monitored using the web platform **ARDA** (arda.af-ix.net)'. A 'DOWNLOAD' button is visible in the bottom right corner.

And their evolution can be monitored using the web platform **ARDA** (arda.af-ix.net)

Week	Date thresholds	# Peering ASNs
Week 1	(2017-09-11 to 2017-09-17)	~100
Week 2	(2017-09-18 to 2017-09-24)	~100
Week 3	(2017-09-25 to 2017-10-01)	~100
Week 4	(2017-10-02 to 2017-10-08)	~100
Week 5	(2017-10-09 to 2017-10-15)	~100

Background & Motivation

Why is this study needed?

- **Recent work**
 - Broadband performance in South Africa
 - Latency and communications performance in Africa
 - Interdomain routing in Africa, routing trends and techno-economic insights in the region
 - Local IXP mapping and their impacts on performance

Background & Motivation

Why is this study needed?

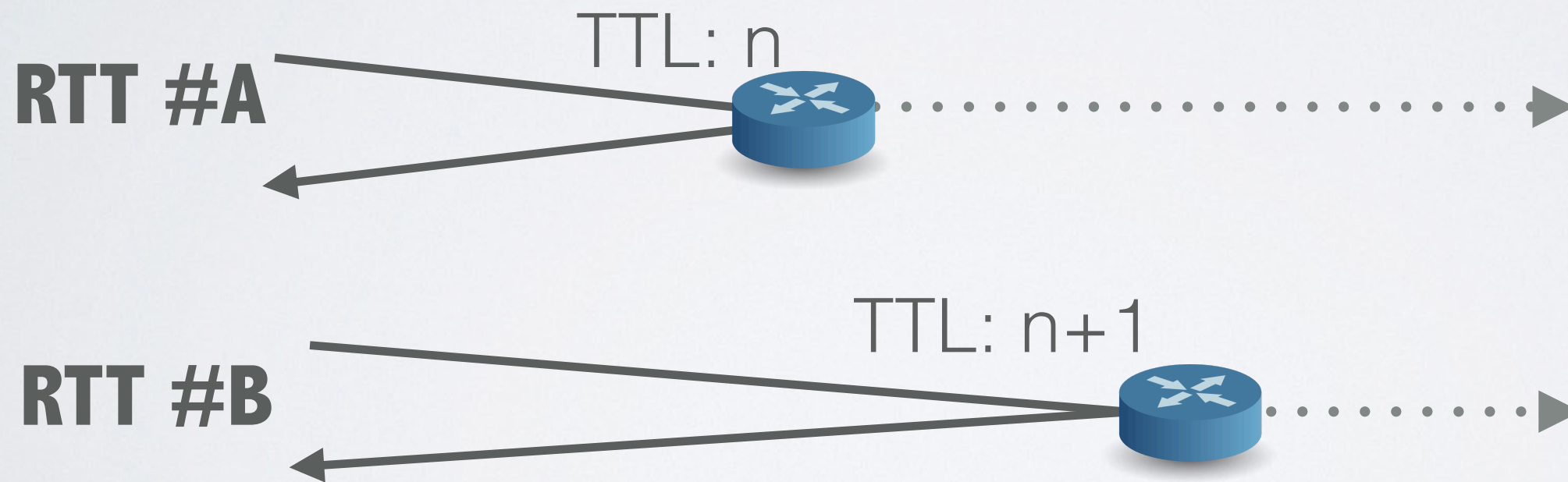
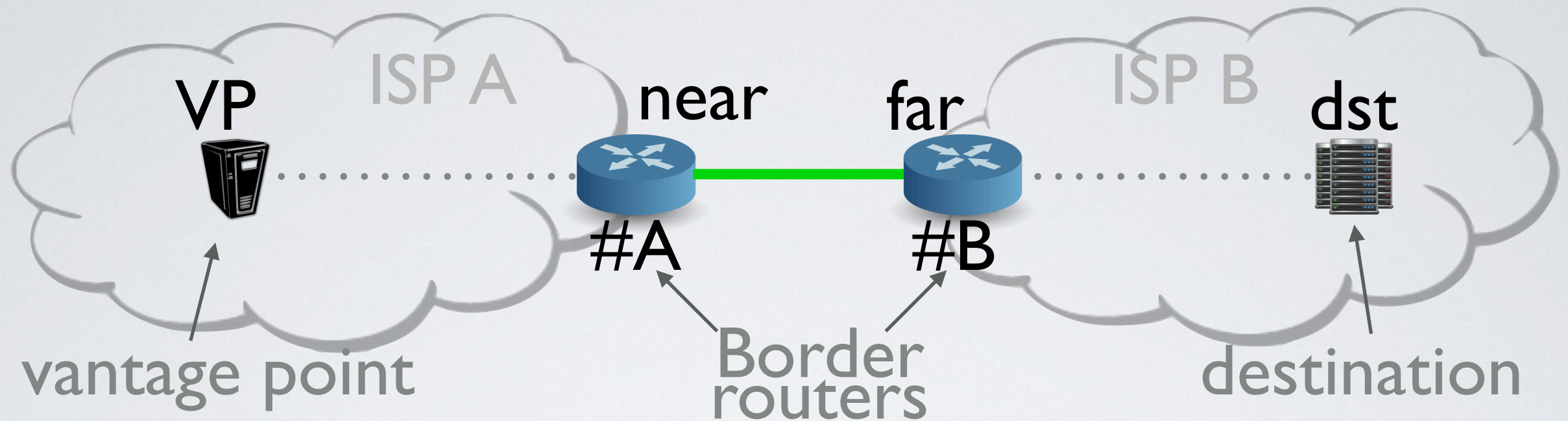
- **Recent work**
 - Broadband performance in South Africa
 - Latency and communications performance in Africa
 - Interdomain routing in Africa, routing trends and techno-economic insights in the region
 - Local IXP mapping and their impacts on performance
- **No study on Congestion at local IXPs**
 - The absence of congestion will incentivize ISPs or CPs that are still reluctant to join those IXPs
 - If there is congestion, what are causes and consequences?

High level overview of our Methodology

1. Deploy Vantage Points (VPs) with visibility into the IXPs
2. Infer the networks present at the IXPs
3. Use the Time-Sequence Latency Probes (TSLP) [1] method to probe each of those networks
4. Look for evidence of congestion

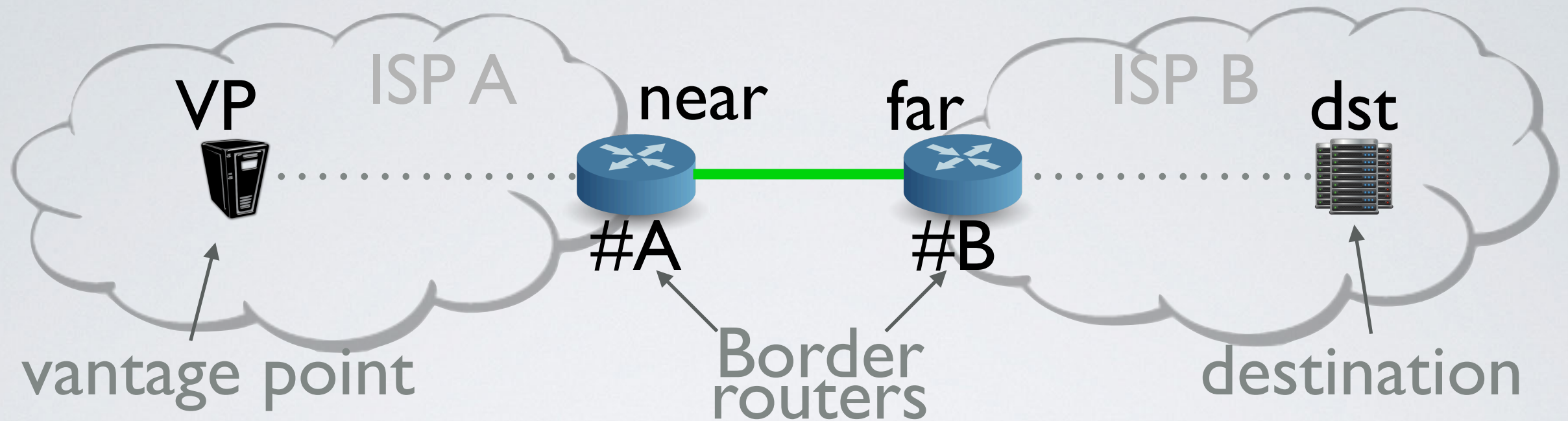
[1] Luckie, Dhamdhere, Clark, Huffaker, Claffy. Challenges in Inferring Internet Interdomain Congestion. In IMC, 2014.

Time Series Latency Probes (TSLP)

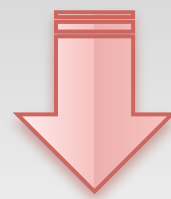


(repeat to obtain a timeseries)

Time Series Latency Probes (TSLP)



Latency elevation on the “far” timeseries,
but no elevation on the “near” timeseries



target link may be congested

Selected Vantage Points (VPs)

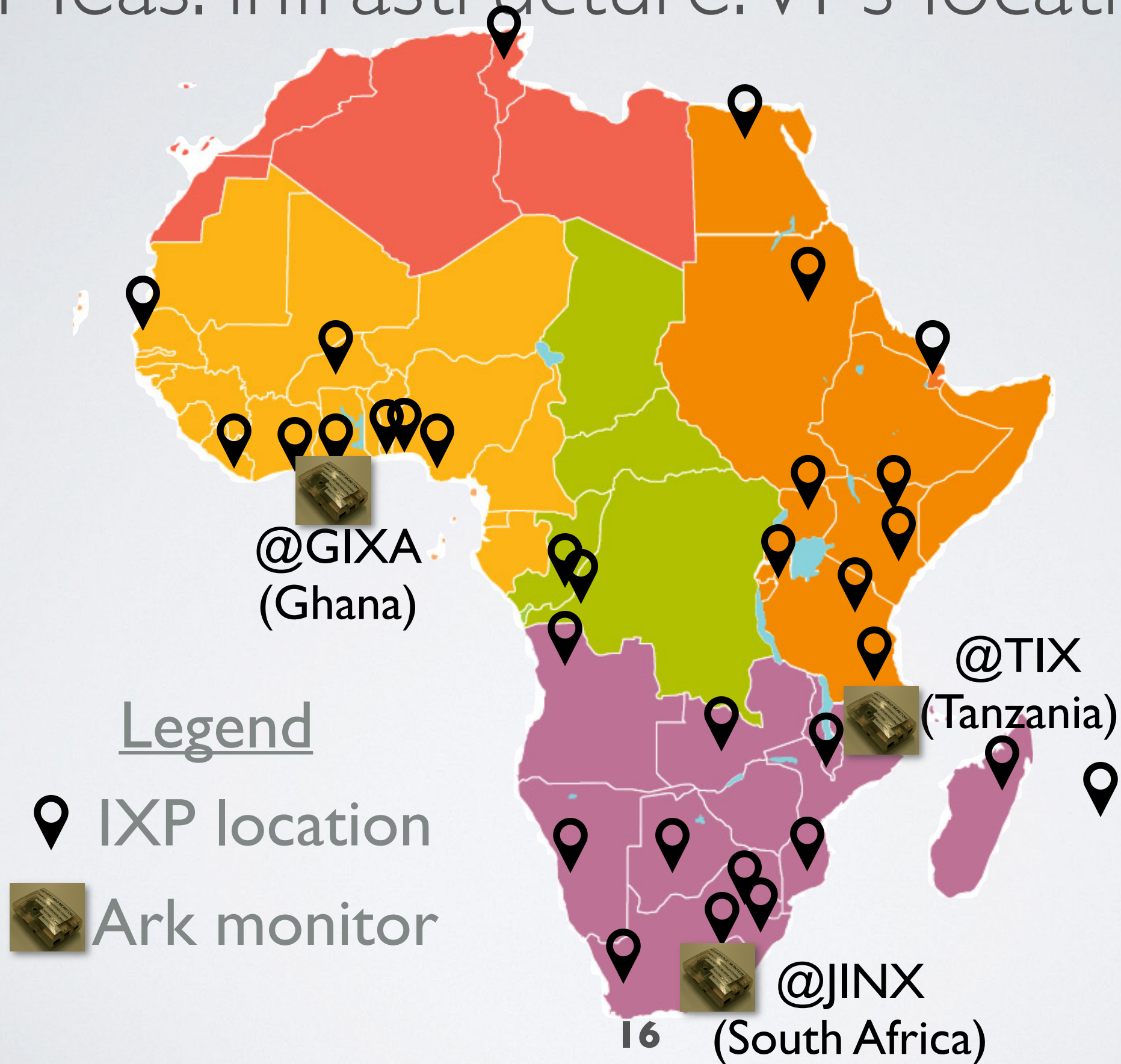
- **Ark monitors deployed at**
 - 6 strategically selected IXPs in Africa: mature markets & potential regional hubs
 - Oldest IXP (JINX) launched in 1996
 - 3 out of 5 African sub-regions covered
- **2 VP setups adopted**
 - Within the content network of the IXP or
 - Within the network of a peer at the IXP



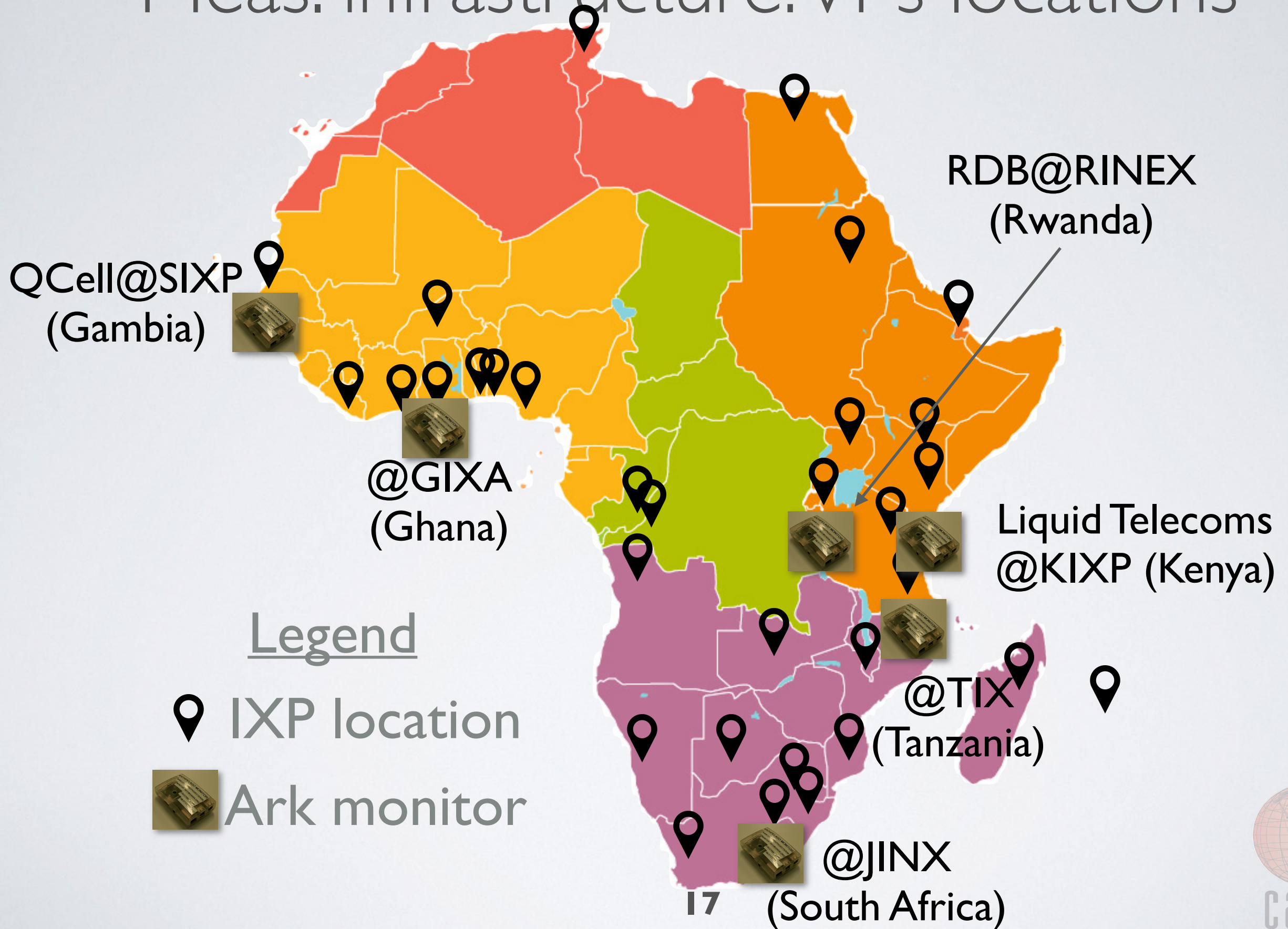
Meas. infrastructure: VPs locations



Meas. infrastructure: VPs locations



Meas. infrastructure: VPs locations



Help build the Ark measurement network in Africa by hosting a VP!

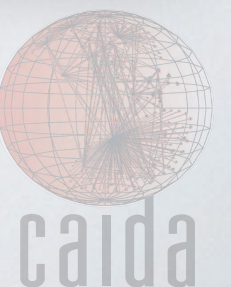
We are always looking for volunteers to host VPs!

Contact us:

manic-info@caida.org

or

roderick@caida.org



Data Collection and Analysis (I)

- **Border mapping**

- Infer the networks present at the IXP using the bdrmap tool [1]
- Validation with 4 VP hosts: **96.2%** neighbors correctly mapped

[1] Luckie, Dhamdhere, Huffaker, Clark, Claffy. bdrmap: Inference of Borders Between IP Networks. In Challenges in Proceedings of ACM SIGCOMM Internet Measurement Conference (IMC). 2016.

[2] Taylor. Change-Point Analysis: A Powerful New Tool for Detecting Changes. <http://www.variation.com/cpa/tech/changepoint.html>, 2000

Data Collection and Analysis (I)

- **Border mapping**

- Infer the networks present at the IXP using the bdrmap tool [1]
- Validation with 4 VP hosts: **96.2%** neighbors correctly mapped

- **TSLP measurements (I)**

- Time range **22/02/2016** to **27/03/2017**
- Low rate TTL-limited probing to both ends of each IP link (**5min**)
- Detect level shifts \geq 10ms magnitude and 30min duration [2]

[1] Luckie, Dhamdhere, Huffaker, Clark, Claffy. bdrmap: Inference of Borders Between IP Networks. In Challenges in Proceedings of ACM SIGCOMM Internet Measurement Conference (IMC). 2016.

[2] Taylor. Change-Point Analysis: A Powerful New Tool for Detecting Changes. <http://www.variation.com/cpa/tech/changepoint.html>, 2000

Data Collection and Analysis (2)

- TSLP measurements (2)

- Record-route (RR) method [3] to check path-symmetry

- IXP operators interviews to validate our results and identify causes of congestion

[3] Katz-Bassett, Madhvastha, Adhikari, Scott, Sherry, Van Wesep, Anderson, Krishnamurthy. Reverse Traceroute. In NSDI, 2010.

Data Collection and Analysis (2)

- **TSLP measurements (2)**

- Record-route (RR) method [3] to check path-symmetry

- IXP operators interviews to validate our results and identify causes of congestion

- **Loss rate measurements**

- Started 5months after TSLP: from **19/07/2016** to **01/04/2017**

- Probing links suffering from repeated congestion (at **1pps**)

- Losses computed over every batch of 100 probes

[3] Katz-Bassett, Madhvastha, Adhikari, Scott, Sherry, Van Wesep, Anderson, Krishnamurthy. Reverse Traceroute. In NSDI, 2010.

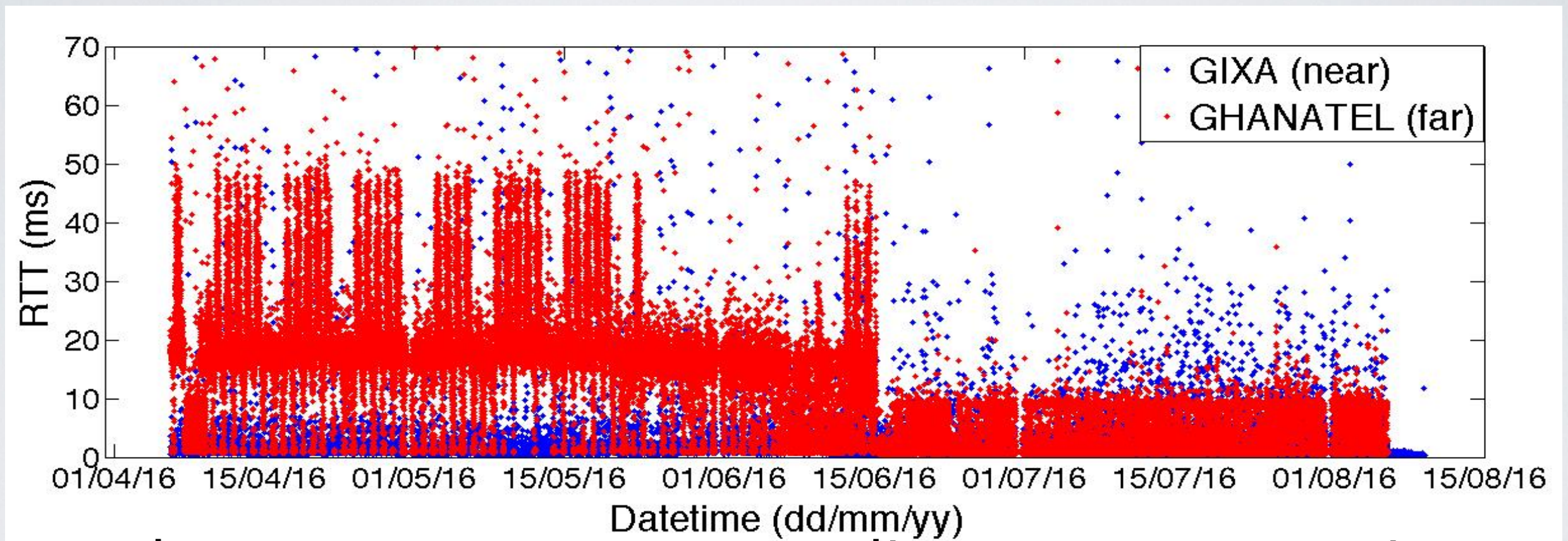
Results Overview

- **No evidence of widespread congestion**
 - 2.2% of discovered link showed evidence of congestion at the end of our measurements campaign
 - Sustained congestion cases: GIXA (VP1)
 - Mitigated congestion cases: TIX (VP2), JINX (VP3), & QCell (VP4)

Results Overview

- **No evidence of widespread congestion**
 - 2.2% of discovered link showed evidence of congestion at the end of our measurements campaign
 - Sustained congestion cases: GIXA (VP1)
 - Mitigated congestion cases: TIX (VP2), JINX (VP3), & QCell (VP4)
- **3 striking cases - (of which 2 are presented)**
 - GIXA (Ghana Internet Exchange Association) - GHANATEL
 - GIXA - KNET (Open discussions)
 - QCELL - NETPAGE

GIXA - GHANATEL

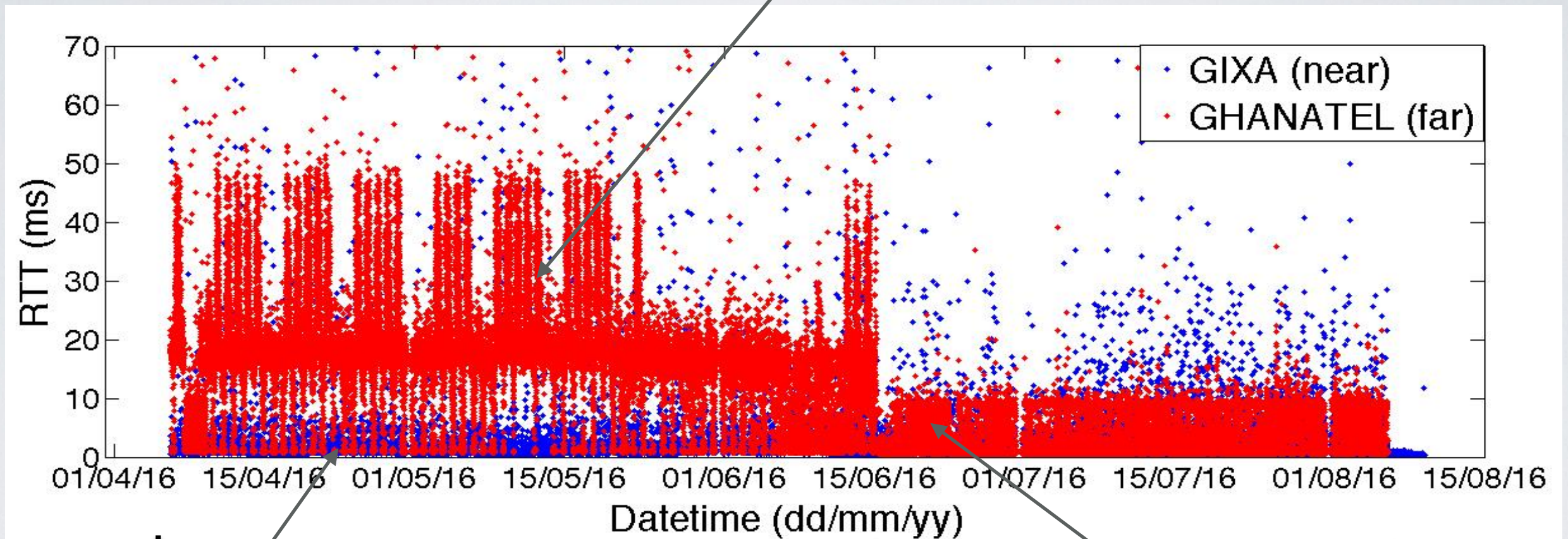


Phase 1

Phase 2

GIXA - GHANATEL

Diurnal pattern on the far-end



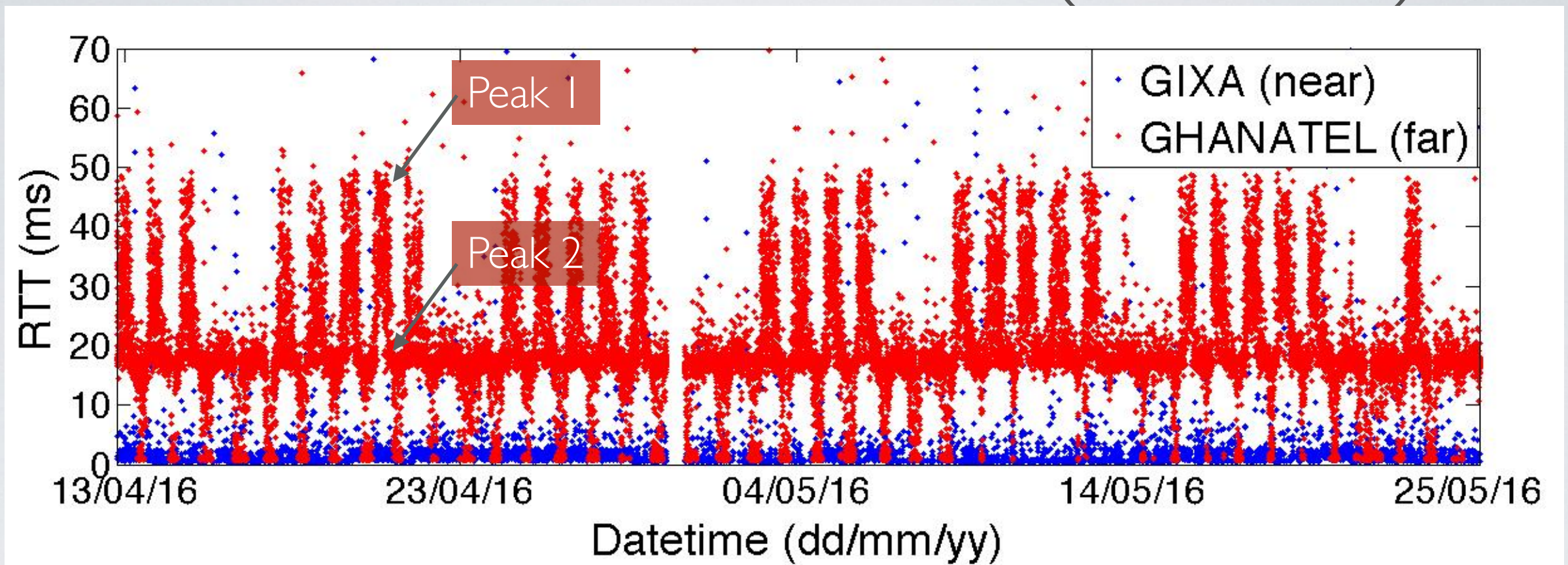
Low and constant RTTs on the near end

Phase 1

Phase 2

Drop of the RTTs to the far-end till the end of the campaign

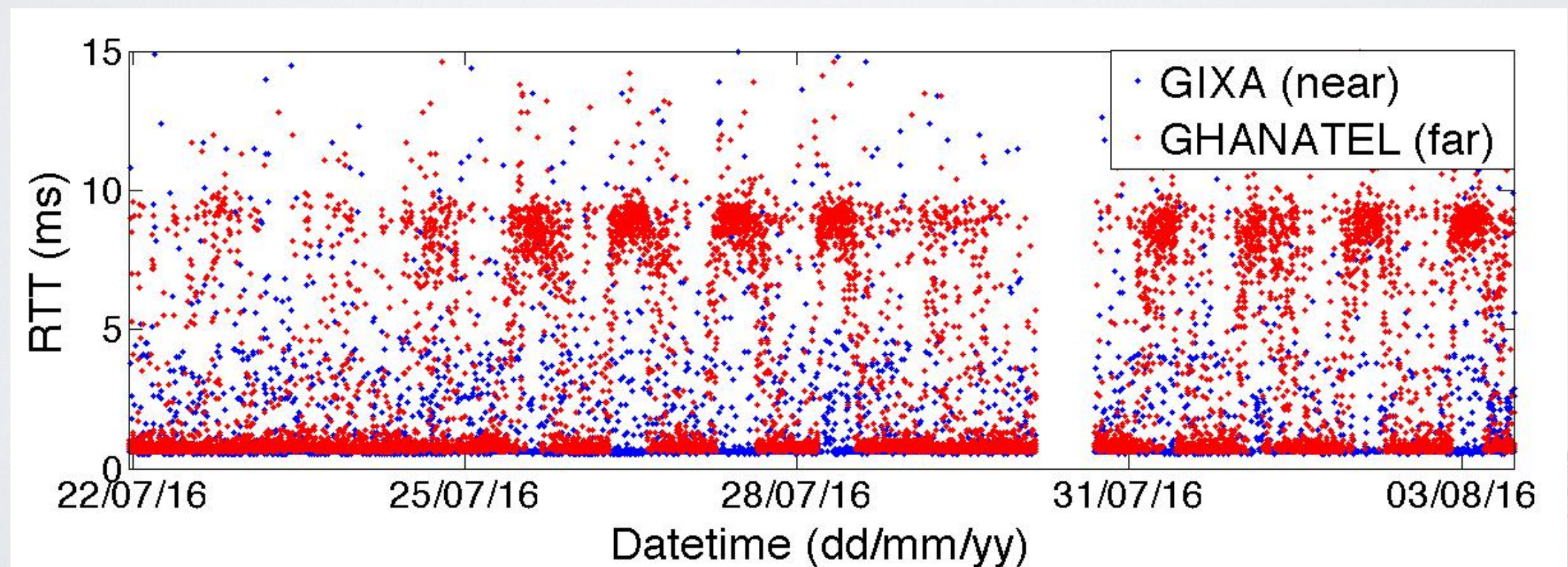
GIXA - GHANATEL (Phase I)



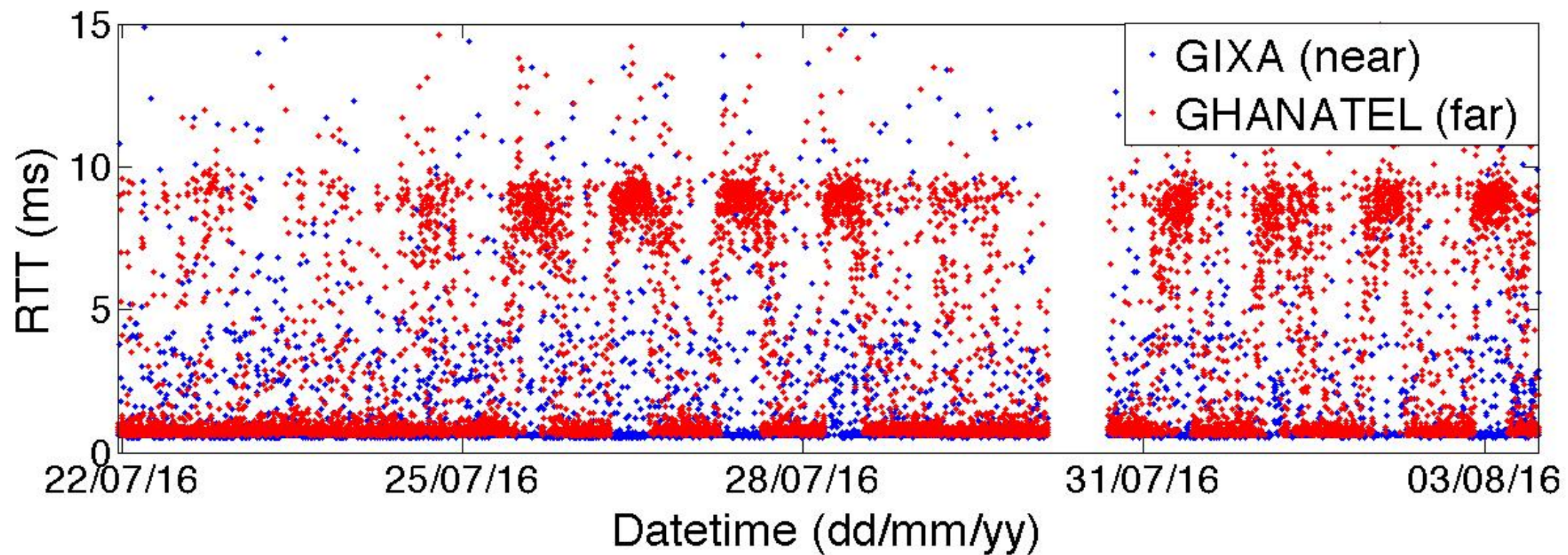
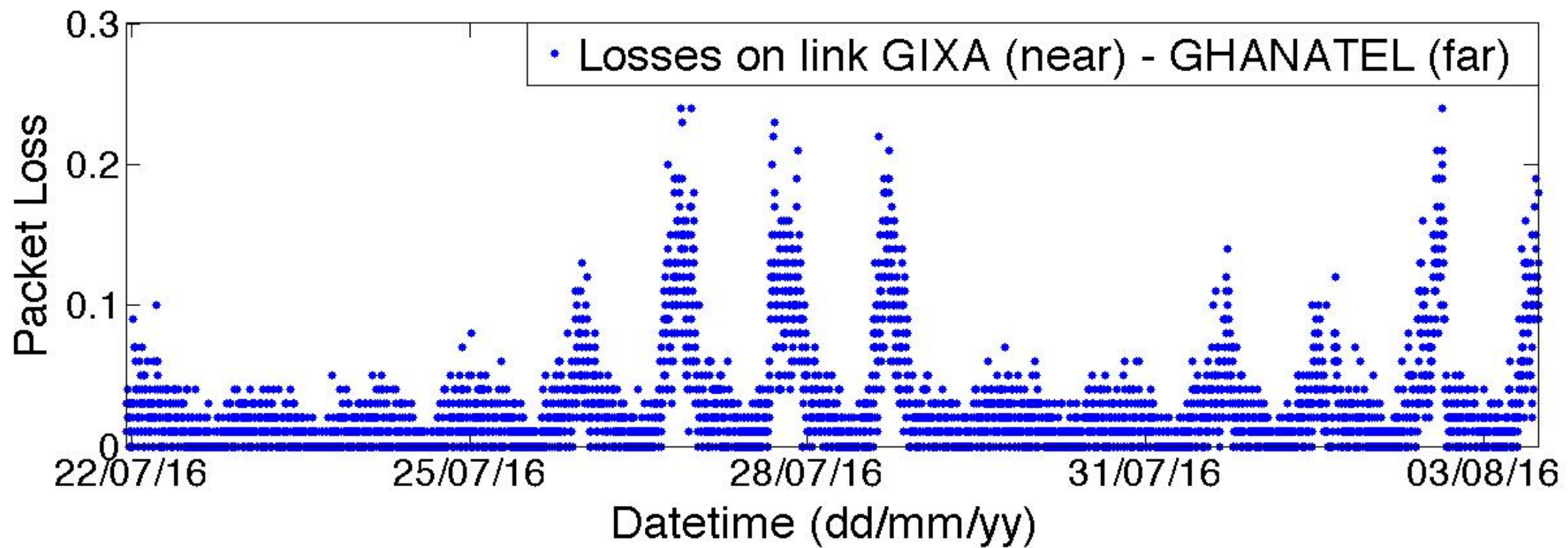
- GHANATEL was providing **free-transit** to the content network hosting the GGCs through a 100 Mbps link
- 100 Mbps link got **congested**
- GHANATEL was serving its client through a separate 1 Gbps link
 - **Its end-users were likely not impacted**

GIXA - GHANATEL (Phase 2)

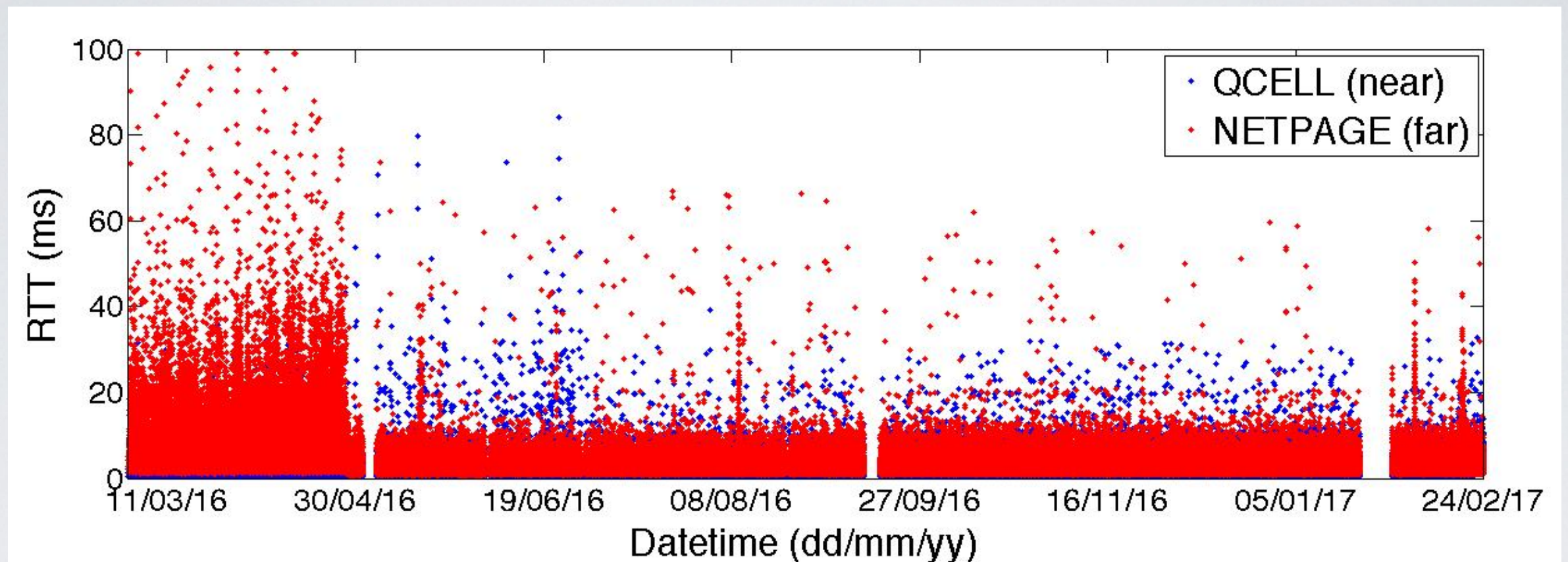
- **Dispute** between IXP and transit
- GHANATEL shut off the transit service to force GIXA to pay!
 - **GGC not functional**: End-users likely affected by the detour of their packets towards Google content
- GHANATEL used the link for peering instead (**but still congested**)



GIXA - GHANATEL (Phase 2)



QCELL - NETPAGE

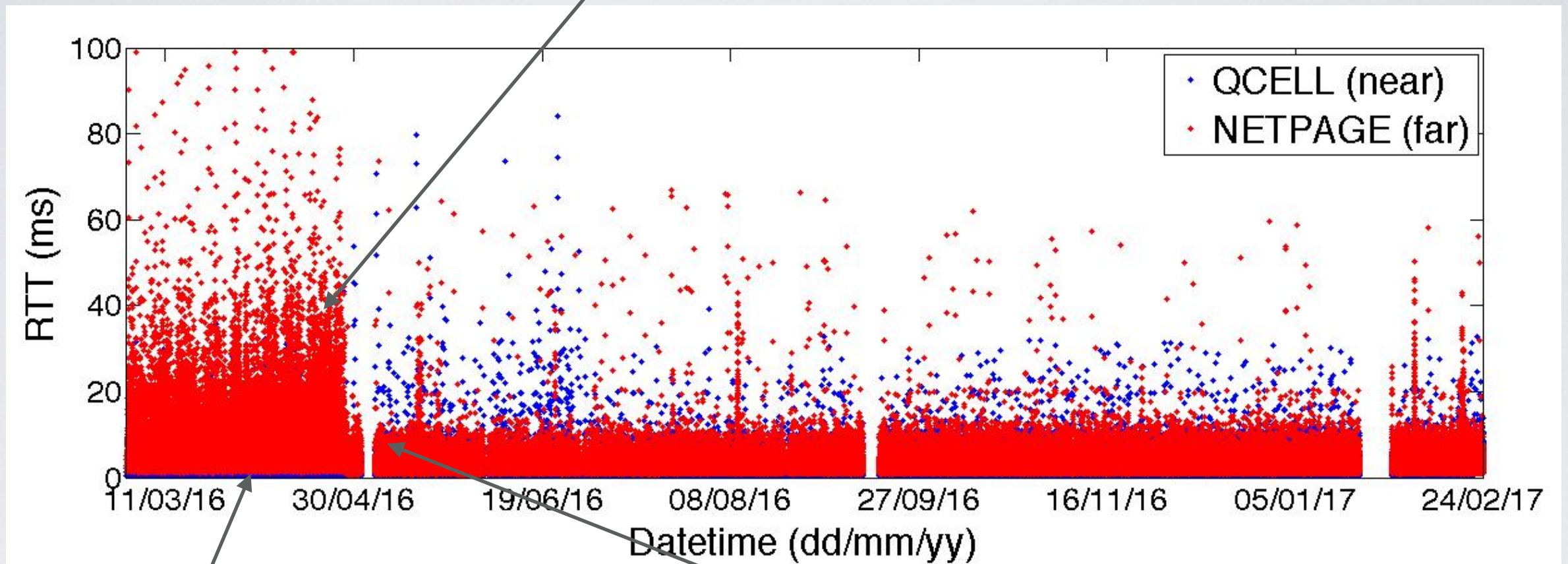


Phase 1

Phase 2

QCELL - NETPAGE

Diurnal pattern on the far-end



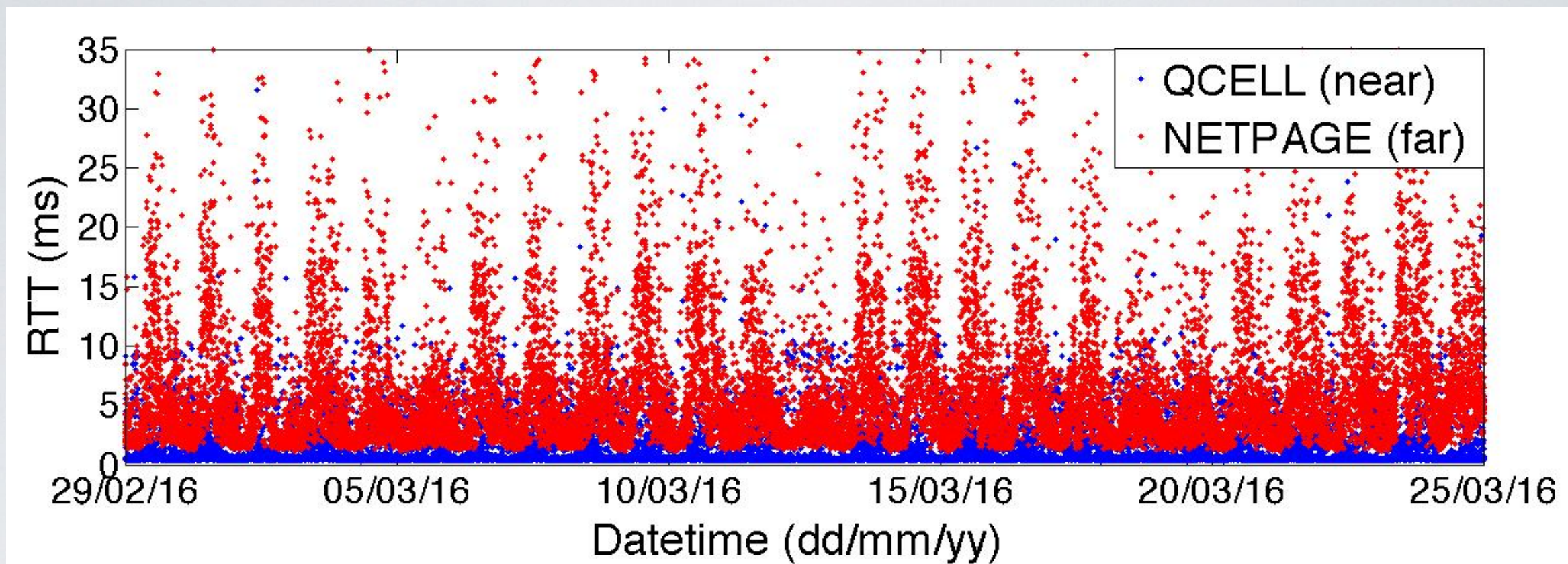
Phase I

Phase 2

Low and constant RTTs on the near end

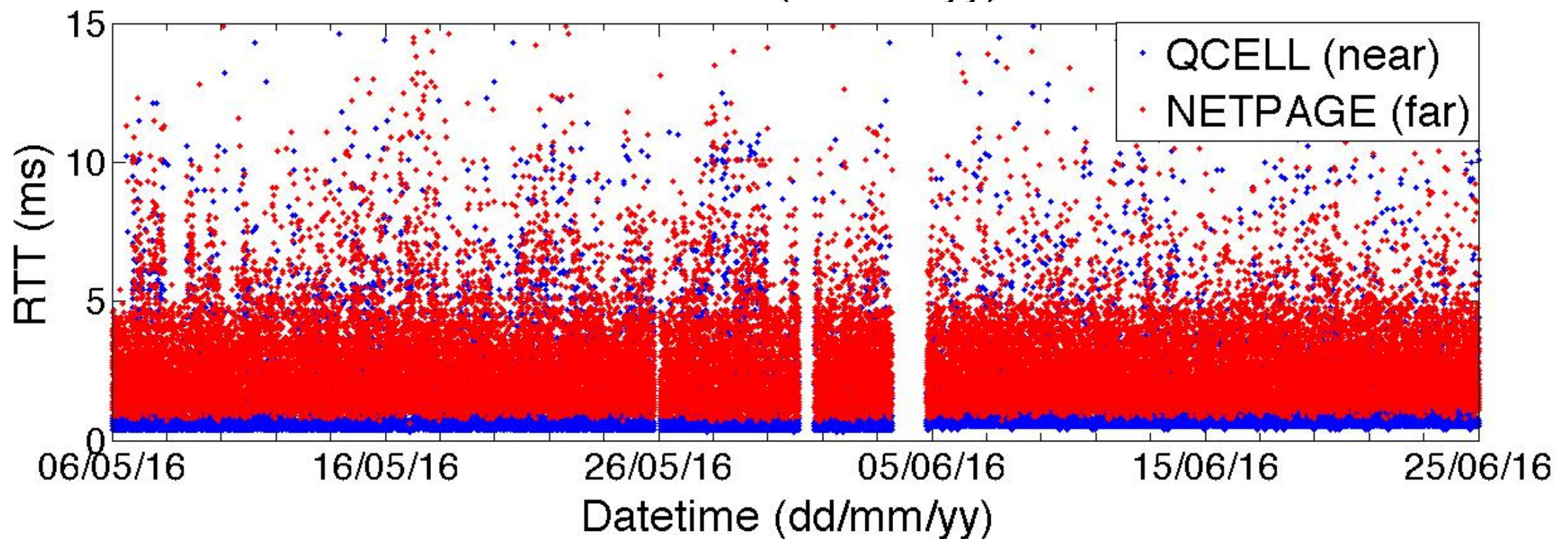
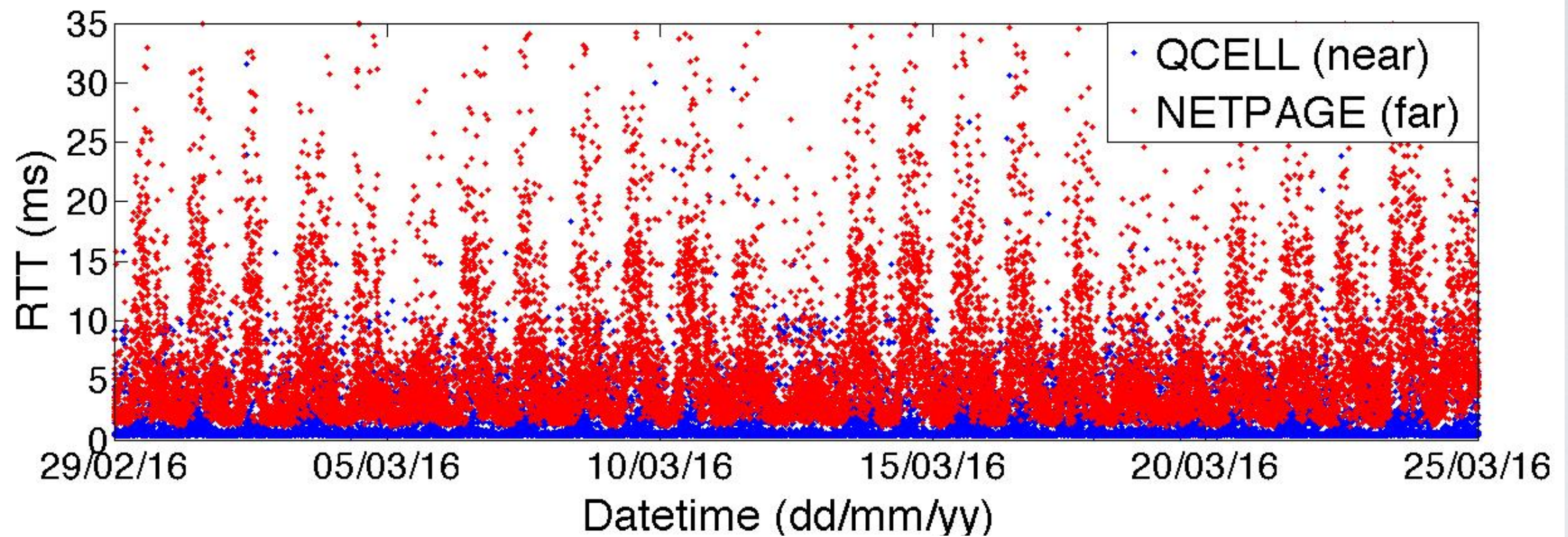
Drop of the RTTs to the far-end till the end of the campaign

QCELL - NETPAGE (Phase I)



- QCell provides transit for GGCs at SIXP
- High bandwidth usage of Google traffic from NETPAGE was degrading performance
- NETPAGE requested an upgrade from 10 Mbps to 1 Gbps

QCELL - NETPAGE (Phase 2)



Conclusions

- Measured IXPs were congestion-free, which promotes peering in the region (see arda.af-ix.net and af-ix.net)
 - IXP ecosystem highly dynamic in Africa => need for a longitudinal measurement and monitoring
 - Need to carefully monitor links used to access content (susceptible to congestion)

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- Discussion with stakeholders is crucial to understanding the causes of performance degradations.

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 - Need to carefully monitor links used to access content (susceptible to congestion)
- Discussion with stakeholders is crucial to understanding the causes of performance degradations
- Must be aware that transit services are needed for updating content caches (this situation may lead to disputes if not well managed)

Related work

- A detailed study on inferring persistent interdomain congestion on the US broadband ISP ecosystem won the 2018 SIGCOMM Best paper award [1].
 - Interested in expanding to African region (co-evolution of topology and congestion dynamics)
 - Would require more monitor deployment
- We are sharing the API to allow network operators and researchers to access the TSLP data collected from involved Ark monitors over the last 2,5 years.

[1] Dhamdhere, A., Clark, D. D., Gamero-Garrido, A., Luckie, M., Mok, R. K., Akiwate, G., ... & Claffy, K. (2018, August). Inferring persistent interdomain congestion. In *Proceedings of the 2018 Conference of the ACM Special Interest Group on Data Communication* (pp. 1-15). ACM.

Open question

How can AFRINIC play a role in sustaining the ARDA platform to enable longitudinal studies of the evolution of the African Internet ecosystem?

<https://arda.af-ix.net/>

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Thank you. Questions?

