graph_ping_data

October 25, 2025

1 CS144 Ping/Traceroute Analysis

Here I visualize and answer questions 1 - 13 in CS144 checkpoint 4. Transmission data is stored in `data/transmission_data/` and traceroutes in `data/traceroute_data/`. I sent transmissions to the university of Queensland Australia at www.uq.edu.au and university of southern california at www.usc.edu. I did a total of 5 different test types all well over an hour. - USC + Wifi (close and wireless intersting connection) - USC + Myth (closed and wired) - Australia + Wifi (far and wireless interesting) - Australia + Cellular (far and wireless interesting) - Australia + Myth (far and wired)

[1]:
```
from __future__ import annotations
import re
import os
from dataclasses import dataclass
from typing import List, Optional, Tuple
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns

sns.set(context="notebook", style="whitegrid")

DATA_ROOT = "/Users/nickallen/Documents/GitHub/CS144/data"
TX_DIR = os.path.join(DATA_ROOT, "transmission_data")
TR_DIR = os.path.join(DATA_ROOT, "traceroute_data")

@dataclass
class PingSample:
    seq: int
    rtt_ms: Optional[float]
    success: bool
    epoch_ts: Optional[float]

LINUX_PING_RE = re.compile(r"^\[(?P<ts>\d+\.\d+)\]\s+64 bytes from .*icmp_seq=(?
 ↪P<seq>\d+) .* time=(?P<rtt>[\d\.]+) ms$")
MAC_PING_RE = re.compile(r"^64 bytes from .*icmp_seq=(?P<seq>-?\d+) .* time=(?
 ↪P<rtt>[\d\.]+) ms$")
MAC_TIMEOUT_RE = re.compile(r"^Request timeout for icmp_seq (?P<seq>-?\d+)$")
```

```python
def parse_ping_file(path: str) -> pd.DataFrame:
    """Parse a ping output file into a DataFrame with columns:
    ['seq','rtt_ms','success','epoch_ts'] sorted by seq.
    Handles Linux (with leading [epoch]) and macOS formats.
    """
    samples: List[PingSample] = []
    with open(path, "r", encoding="utf-8", errors="ignore") as f:
        for line in f:
            line = line.strip()
            if not line:
                continue
            m = LINUX_PING_RE.match(line)
            if m:
                samples.append(PingSample(
                    seq=int(m.group("seq")),
                    rtt_ms=float(m.group("rtt")),
                    success=True,
                    epoch_ts=float(m.group("ts")),
                ))
                continue
            m = MAC_PING_RE.match(line)
            if m:
                samples.append(PingSample(
                    seq=int(m.group("seq")),
                    rtt_ms=float(m.group("rtt")),
                    success=True,
                    epoch_ts=None,
                ))
                continue
            m = MAC_TIMEOUT_RE.match(line)
            if m:
                samples.append(PingSample(
                    seq=int(m.group("seq")),
                    rtt_ms=None,
                    success=False,
                    epoch_ts=None,
                ))
                continue
            # ignore header or other lines
    df = pd.DataFrame([s.__dict__ for s in samples])
    if df.empty:
        return df
    df = df.sort_values("seq").reset_index(drop=True)
    # Create relative time if epoch present and mostly filled
    if df["epoch_ts"].notna().mean() > 0.5:
        t0 = df["epoch_ts"].dropna().iloc[0]
        df["t_sec"] = df["epoch_ts"].fillna(method="ffill").fillna(method="bfill") - t0
    else:
        # approximate assuming 1s spacing
        df["t_sec"] = (df["seq"] - df["seq"].min()).astype(float)
    return df


def longest_streak(series: pd.Series, target: bool) -> int:
    best = cur = 0
    for val in series:
        if bool(val) == target:
            cur += 1
            best = max(best, cur)
        else:
            cur = 0
    return best


def packet_loss_autocorr(success_series: pd.Series, k_values: List[int]) -> pd.DataFrame:
    """Conditional delivery rates given success/loss at offset k.
    Returns DataFrame with columns ['k','P(reply|reply)','P(loss|loss)'] with NaNs when undefined.
    """
    x = success_series.astype(int).to_numpy()
    out = []
    n = len(x)
    for k in k_values:
        if k == 0:
            out.append((k, np.nan, np.nan))
            continue
        if k > 0:
            a = x[:-k]
            b = x[k:]
        else:
            a = x[-k:]
            b = x[:k]
        # P(reply_{n+k}=1 | reply_n=1)
        mask_reply = a == 1
        mask_loss = a == 0
        pr = b[mask_reply].mean() if mask_reply.any() else np.nan
        pl = (1 - b[mask_loss]).mean() if mask_loss.any() else np.nan
        out.append((k, pr, pl))
    return pd.DataFrame(out, columns=["k", "P_reply_given_reply", "P_loss_given_loss"])
```

[2]:
```
# Load all ping datasets
from glob import glob

ping_files = sorted(glob(os.path.join(TX_DIR, "*.txt")))
{pf: os.path.basename(pf) for pf in ping_files}
```

[2]:
```
{'/Users/nickallen/Documents/GitHub/CS144/data/transmission_data/computer_to_aus
tralia_stanfod_hotspot_data.txt':
'computer_to_australia_stanfod_hotspot_data.txt',
 '/Users/nickallen/Documents/GitHub/CS144/data/transmission_data/computer_to_aus
tralia_stanfod_wifi_data.txt': 'computer_to_australia_stanfod_wifi_data.txt',
 '/Users/nickallen/Documents/GitHub/CS144/data/transmission_data/labtop_to_usc_s
tanford_wifi.txt': 'labtop_to_usc_stanford_wifi.txt',
 '/Users/nickallen/Documents/GitHub/CS144/data/transmission_data/myth_to_austral
ia_data.txt': 'myth_to_australia_data.txt',
 '/Users/nickallen/Documents/GitHub/CS144/data/transmission_data/usc_myth_data.t
xt': 'usc_myth_data.txt'}
```

[3]:
```
# Parse and combine to a single DataFrame with a dataset label
frames = []
for pf in ping_files:
    df = parse_ping_file(pf)
    df["dataset"] = os.path.basename(pf)
    frames.append(df)

pings = pd.concat(frames, ignore_index=True)
pings.head()
```

```
/var/folders/jl/kxty9ftx6jz4jnztx5wctvt40000gn/T/ipykernel_53835/3313088552.py:7
5: FutureWarning: Series.fillna with 'method' is deprecated and will raise in a
future version. Use obj.ffill() or obj.bfill() instead.
  df["t_sec"] = df["epoch_ts"].fillna(method="ffill").fillna(method="bfill") -
t0
/var/folders/jl/kxty9ftx6jz4jnztx5wctvt40000gn/T/ipykernel_53835/3313088552.py:7
5: FutureWarning: Series.fillna with 'method' is deprecated and will raise in a
future version. Use obj.ffill() or obj.bfill() instead.
  df["t_sec"] = df["epoch_ts"].fillna(method="ffill").fillna(method="bfill") -
t0
/var/folders/jl/kxty9ftx6jz4jnztx5wctvt40000gn/T/ipykernel_53835/2860007488.py:8
: FutureWarning: The behavior of DataFrame concatenation with empty or all-NA
entries is deprecated. In a future version, this will no longer exclude empty or
all-NA columns when determining the result dtypes. To retain the old behavior,
exclude the relevant entries before the concat operation.
  pings = pd.concat(frames, ignore_index=True)
```

[3]:
```
   seq   rtt_ms  success  epoch_ts  t_sec  \
0    0      NaN    False       NaN    0.0
1    0  218.535     True       NaN    0.0
```

```
2     1  215.867     True        NaN     1.0
3     2  201.771     True        NaN     2.0
4     3  211.031     True        NaN     3.0

                                          dataset
0  computer_to_australia_stanfod_hotspot_data.txt
1  computer_to_australia_stanfod_hotspot_data.txt
2  computer_to_australia_stanfod_hotspot_data.txt
3  computer_to_australia_stanfod_hotspot_data.txt
4  computer_to_australia_stanfod_hotspot_data.txt
```

1.1 Q1. Overall delivery rate over entire interval

Delivery rate = number of echo replies received / number of echo requests sent. Missing sequence numbers indicate lost replies.

[4]:

```python
def compute_delivery_rate(df: pd.DataFrame) -> float:
    if df.empty:
        return float("nan")
    seq_min, seq_max = int(df["seq"].min()), int(df["seq"].max())
    total_sent = seq_max - seq_min + 1
    received = int(df["success"].sum())
    return received / total_sent

rates = pings.groupby("dataset").apply(compute_delivery_rate).
 ↪rename("delivery_rate").reset_index()
rates
```

```
/var/folders/jl/kxty9ftx6jz4jnztx5wctvt40000gn/T/ipykernel_53835/2137780500.py:9
: FutureWarning: DataFrameGroupBy.apply operated on the grouping columns. This
behavior is deprecated, and in a future version of pandas the grouping columns
will be excluded from the operation. Either pass `include_groups=False` to
exclude the groupings or explicitly select the grouping columns after groupby to
silence this warning.
  rates = pings.groupby("dataset").apply(compute_delivery_rate).rename("delivery
_rate").reset_index()
```

[4]:

```
                                          dataset  delivery_rate
0  computer_to_australia_stanfod_hotspot_data.txt       0.999464
1     computer_to_australia_stanfod_wifi_data.txt       1.000000
2                 labtop_to_usc_stanford_wifi.txt       5.333740
3                      myth_to_australia_data.txt       0.999968
4                               usc_myth_data.txt       1.000000
```

1.2 Q2. Longest consecutive string of successful pings

```
[5]: success_streaks = (
         pings.sort_values(["dataset","seq"])
              .groupby("dataset")["success"].apply(lambda s: longest_streak(s, True))
              .rename("longest_success_streak")
              .reset_index()
     )
     success_streaks
```

```
[5]:                                          dataset  longest_success_streak
     0  computer_to_australia_stanfod_hotspot_data.txt                    6289
     1     computer_to_australia_stanfod_wifi_data.txt                   17893
     2                 labtop_to_usc_stanford_wifi.txt                   23655
     3                     myth_to_australia_data.txt                   30970
     4                              usc_myth_data.txt                     202
```

1.3 Q3. Longest burst of losses

```
[6]: loss_streaks = (
         pings.sort_values(["dataset","seq"])
              .groupby("dataset")["success"].apply(lambda s: longest_streak(s,␣
      ↪False))
              .rename("longest_loss_burst")
              .reset_index()
     )
     loss_streaks
```

```
[6]:                                          dataset  longest_loss_burst
     0  computer_to_australia_stanfod_hotspot_data.txt                   1
     1     computer_to_australia_stanfod_wifi_data.txt                   1
     2                 labtop_to_usc_stanford_wifi.txt                   1
     3                     myth_to_australia_data.txt                   0
     4                              usc_myth_data.txt                   0
```

1.4 Q4. Geographic path from traceroute

```
[7]: # Summarize visible named hops per traceroute file
     from collections import defaultdict

     trace_files = sorted(glob(os.path.join(TR_DIR, "*.txt")))
     tr_summaries = {}
     for tf in trace_files:
         hops = []
         with open(tf, "r", encoding="utf-8", errors="ignore") as f:
             for line in f:
                 line = line.strip()
```

```
            if not line or line.startswith("traceroute "):
                continue
            if "* * *" in line:
                continue
            # capture the hostname/ip in parentheses if present
            parts = line.split()
            if len(parts) >= 2:
                hops.append(" ".join(parts[1:3]))
    tr_summaries[os.path.basename(tf)] = hops
tr_summaries
```

[7]:

```
{'laptop_to_australia_traceroute.txt': ['10.27.112.2 (10.27.112.2)',
  'xb-east-rtr-vlan11.sunet (171.64.0.194)',
  'hpr-svl-rtr-vlan3.sunet (171.66.255.147)',
  'hpr-svl-hpr3--stan-100ge.cenic.net (137.164.27.60)',
  'aarnet-2-is-jmb-778.sttlwa.pacificwave.net (207.231.245.4)',
  'et-10-0-5.170.pe1.brwy.nsw.aarnet.net.au (113.197.15.62)',
  'et-7-1-0.pe1.brwy.nsw.aarnet.net.au (113.197.15.13)',
  'et-0-3-0.pe1.gdpt.qld.aarnet.net.au (113.197.15.17)',
  '138.44.129.158 (138.44.129.158)',
  'fw-a-gw10.router.uq.edu.au (130.102.0.193)',
  'se10-fw-a.router.uq.edu.au (130.102.159.61)',
  'www-test.uq.edu.au (130.102.184.3)'],
 'laptop_to_usc_traceroute.txt': ['10.27.112.2 (10.27.112.2)',
  'xb-east-rtr-vlan11.sunet (171.64.0.194)',
  'dc-sf-rtr-vl2.sunet (171.64.255.146)',
  '(171.66.255.146) 3.550',
  'dc-sfo-agg4--stanford-100g.cenic.net (137.164.23.178)',
  'dc-snvl2-agg-01--sfra1-agg-01-100gbe.cenic.net (137.164.11.92)',
  'dc-svl-agg10--snvl2-agg-01-400g.cenic.net (137.164.11.80)'],
 'myth_to_autralia_traceroute.txt': ['csee-rtf-rtr-vl3803.SUNet (171.64.15.3)',
  'hpr-svl-rtr-vlan12.SUNet (171.66.0.214)',
  'hpr-svl-hpr3--stan-100ge.cenic.net (137.164.27.60)',
  'aarnet-2-is-jmb-778.sttlwa.pacificwave.net (207.231.245.4)',
  'et-10-0-5.170.pe1.brwy.nsw.aarnet.net.au (113.197.15.62)',
  'et-7-1-0.pe1.brwy.nsw.aarnet.net.au (113.197.15.13)',
  'et-0-3-0.pe1.gdpt.qld.aarnet.net.au (113.197.15.17)',
  '138.44.129.158 (138.44.129.158)',
  'fw-a-gw10.router.uq.edu.au (130.102.0.193)',
  'se10-fw-a.router.uq.edu.au (130.102.159.61)',
  'www.its.uq.edu.au (130.102.184.3)'],
 'myth_to_usc_traceroute.txt': ['csee-rtf-rtr-vl3803.SUNet (171.64.15.3)',
  'dc-sf-rtr-vl12.SUNet (171.66.0.207)',
  'dc-sfo-agg4--stanford-100g.cenic.net (137.164.23.178)',
  'dc-snvl2-agg-01--sfra1-agg-01-100gbe.cenic.net (137.164.11.92)',
  'dc-svl-agg10--snvl2-agg-01-400g.cenic.net (137.164.11.80)']}
```

1.4.1 Readable traceroute summary (all hops)

[8]:

```python
# Pretty-print full traceroutes with all hops, preserving '*' lines
from textwrap import shorten

for tf in sorted(glob(os.path.join(TR_DIR, "*.txt"))):
    print(f"\n=== {os.path.basename(tf)} ===")
    with open(tf, "r", encoding="utf-8", errors="ignore") as f:
        hop_num = 0
        for raw in f:
            line = raw.rstrip("\n")
            if not line or line.startswith("traceroute "):
                continue
            hop_num += 1
            # collapse extra spaces for readability but keep stars
            cleaned = " ".join(line.split())
            print(f"{hop_num:>2}: {cleaned}")
```

```
=== laptop_to_australia_traceroute.txt ===
 1: 1 10.27.112.2 (10.27.112.2) 3.651 ms 3.235 ms 2.117 ms
 2: 2 xb-east-rtr-vlan11.sunet (171.64.0.194) 3.217 ms 2.609 ms 3.986 ms
 3: 3 hpr-svl-rtr-vlan3.sunet (171.66.255.147) 6.783 ms 3.189 ms 4.382 ms
 4: 4 hpr-svl-hpr3--stan-100ge.cenic.net (137.164.27.60) 4.615 ms 3.316 ms 3.399
ms
 5: 5 aarnet-2-is-jmb-778.sttlwa.pacificwave.net (207.231.245.4) 19.882 ms
20.543 ms 21.804 ms
 6: 6 et-10-0-5.170.pe1.brwy.nsw.aarnet.net.au (113.197.15.62) 234.173 ms
159.678 ms 157.617 ms
 7: 7 et-7-1-0.pe1.brwy.nsw.aarnet.net.au (113.197.15.13) 200.378 ms 218.672 ms
157.709 ms
 8: 8 et-0-3-0.pe1.gdpt.qld.aarnet.net.au (113.197.15.17) 172.916 ms 176.652 ms
172.709 ms
 9: 9 138.44.129.158 (138.44.129.158) 177.420 ms 174.549 ms 174.031 ms
10: 10 fw-a-gw10.router.uq.edu.au (130.102.0.193) 201.512 ms 180.045 ms 224.624
ms
11: 11 se10-fw-a.router.uq.edu.au (130.102.159.61) 263.520 ms 174.616 ms 173.740
ms
12: 12 * * *
13: 13 * * *
14: 14 * * *
15: 15 * * *
16: 16 www-test.uq.edu.au (130.102.184.3) 174.190 ms 238.289 ms 173.657 ms

=== laptop_to_usc_traceroute.txt ===
 1: 1 10.27.112.2 (10.27.112.2) 3.873 ms 2.939 ms 1.957 ms
 2: 2 xb-east-rtr-vlan11.sunet (171.64.0.194) 2.238 ms 2.933 ms 2.899 ms
 3: 3 dc-sf-rtr-vl2.sunet (171.64.255.146) 3.589 ms 5.280 ms
```

```
dc-sf-rtr-vl3.sunet (171.66.255.146) 3.550 ms
4 dc-sfo-agg4--stanford-100g.cenic.net (137.164.23.178) 7.367 ms 4.283 ms
4.471 ms
5 dc-snvl2-agg-01--sfra1-agg-01-100gbe.cenic.net (137.164.11.92) 4.622 ms
4.326 ms 3.661 ms
6 dc-svl-agg10--snvl2-agg-01-400g.cenic.net (137.164.11.80) 4.143 ms 3.718
ms 4.448 ms
7 * * *
8 * * *
9 * * *
10 * * *
11 * * *
12 * * *
13 * * *
14 * * *
15 * * *
16 * * *
17 * * *
18 * * *
19 * * *
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31 * * *
32 * * *
33 * * *
34 * * *
35 * * *
36 * * *
37 * * *
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39 * * *
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42 * * *
43 * * *
44 * * *
45 * * *
46 * * *
47 * * *
```

```
49: 48 * * *
50: 49 * * *
51: 50 * * *
52: 51 * * *
53: 52 * * *
54: 53 * * *
55: 54 * * *
56: 55 * * *
57: 56 * * *
58: 57 * * *
59: 58 * * *
60: 59 * * *
61: 60 * * *
62: 61 * * *
63: 62 * * *
64: 63 * * *
65: 64 * * *

=== myth_to_autralia_traceroute.txt ===
 1: 1 csee-rtf-rtr-vl3803.SUNet (171.64.15.3) 0.500 ms csee-west-rtr-
vl3803.SUNet (171.64.15.2) 0.266 ms csee-rtf-rtr-vl3803.SUNet (171.64.15.3)
0.356 ms
 2: 2 hpr-svl-rtr-vlan12.SUNet (171.66.0.214) 3.976 ms 0.724 ms 0.630 ms
 3: 3 hpr-svl-hpr3--stan-100ge.cenic.net (137.164.27.60) 1.600 ms 1.545 ms 1.565
ms
 4: 4 aarnet-2-is-jmb-778.sttlwa.pacificwave.net (207.231.245.4) 18.478 ms
18.422 ms 18.367 ms
 5: 5 et-10-0-5.170.pe1.brwy.nsw.aarnet.net.au (113.197.15.62) 155.232 ms
155.176 ms 155.121 ms
 6: 6 et-7-1-0.pe1.brwy.nsw.aarnet.net.au (113.197.15.13) 155.288 ms 155.706 ms
155.505 ms
 7: 7 et-0-3-0.pe1.gdpt.qld.aarnet.net.au (113.197.15.17) 195.282 ms 195.115 ms
195.055 ms
 8: 8 138.44.129.158 (138.44.129.158) 170.939 ms 171.321 ms 170.939 ms
 9: 9 fw-a-gw10.router.uq.edu.au (130.102.0.193) 171.092 ms 171.164 ms 171.077
ms
10: 10 se10-fw-a.router.uq.edu.au (130.102.159.61) 181.355 ms 171.797 ms 171.840
ms
11: 11 * * *
12: 12 * * *
13: 13 * * *
14: 14 * * *
15: 15 www.its.uq.edu.au (130.102.184.3) 171.238 ms 171.246 ms 171.052 ms

=== myth_to_usc_traceroute.txt ===
 1: 1 csee-rtf-rtr-vl3803.SUNet (171.64.15.3) 0.507 ms 0.483 ms csee-west-rtr-
vl3803.SUNet (171.64.15.2) 0.275 ms
 2: 2 dc-sf-rtr-vl12.SUNet (171.66.0.207) 4.211 ms 4.191 ms 4.175 ms
 3: 3 dc-sfo-agg4--stanford-100g.cenic.net (137.164.23.178) 1.203 ms 1.187 ms
1.171 ms
 4: 4 dc-snvl2-agg-01--sfra1-agg-01-100gbe.cenic.net (137.164.11.92) 1.797 ms
1.729 ms 1.660 ms
 5: 5 dc-svl-agg10--snvl2-agg-01-400g.cenic.net (137.164.11.80) 1.447 ms 1.425
ms 1.408 ms
 6: 6 * * *
 7: 7 * * *
 8: 8 * * *
 9: 9 * * *
10: 10 * * *
11: 11 * * *
12: 12 * * *
13: 13 * * *
14: 14 * * *
15: 15 * * *
16: 16 * * *
17: 17 * * *
18: 18 * * *
19: 19 * * *
20: 20 * * *
21: 21 * * *
22: 22 * * *
23: 23 * * *
24: 24 * * *
25: 25 * * *
26: 26 * * *
27: 27 * * *
28: 28 * * *
29: 29 * * *
30: 30 * * *
```

I was unable to deduce the path by using the traceroute. However, for every route we can see the packages leaving stanford with the endings of .sunet. This means that we did some work to get off stanford's campus which is as expected. Also, many of the names end in .edu, which makes me thinkt that a lot of the routers are at different universities. I was surprised however that it only took 15 hops from myth to reach the australia end point and only took 16 hops to reach from the computer. I was not quite sure what to make out the *** entries.

1.5 Q5. Autocorrelation of packet loss

For k in [-10, 10], compute conditional delivery rates given success or loss k steps apart.

[9]:

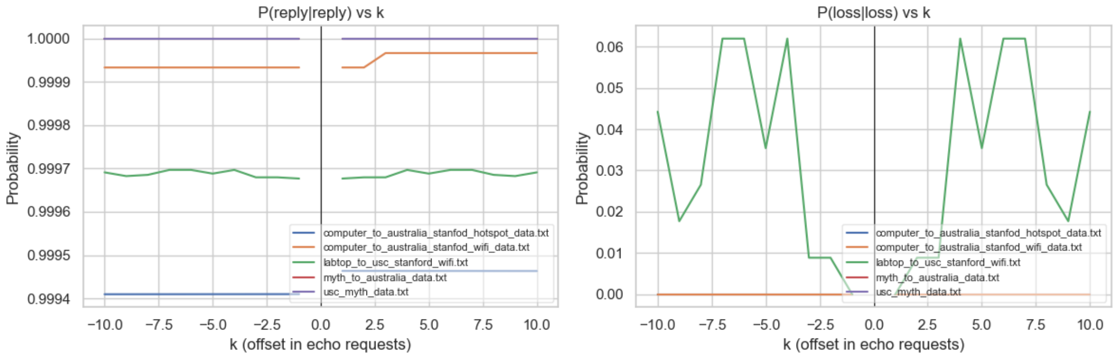
```python
k_values = list(range(-10, 11))
autocorr_frames = []
for name, df in pings.groupby("dataset"):
    ac = packet_loss_autocorr(df["success"], k_values)
    ac["dataset"] = name
    autocorr_frames.append(ac)
autocorr = pd.concat(autocorr_frames, ignore_index=True)
autocorr_pivot = autocorr.pivot(index="k", columns="dataset",␣
 ↪values="P_reply_given_reply")
autocorr_loss_pivot = autocorr.pivot(index="k", columns="dataset",␣
 ↪values="P_loss_given_loss")
autocorr.head()
```

[9]:

```
    k  P_reply_given_reply  P_loss_given_loss  \
0 -10             0.999409                0.0
1  -9             0.999410                0.0
2  -8             0.999410                0.0
3  -7             0.999410                0.0
4  -6             0.999410                0.0

                                      dataset
0  computer_to_australia_stanfod_hotspot_data.txt
1  computer_to_australia_stanfod_hotspot_data.txt
2  computer_to_australia_stanfod_hotspot_data.txt
3  computer_to_australia_stanfod_hotspot_data.txt
4  computer_to_australia_stanfod_hotspot_data.txt
```

[10]:

```
fig, axes = plt.subplots(1, 2, figsize=(12,4), sharex=True, sharey=False)
autocorr_pivot.plot(ax=axes[0], title="P(reply|reply) vs k")
autocorr_loss_pivot.plot(ax=axes[1], title="P(loss|loss) vs k")
for ax in axes:
    ax.set_xlabel("k (offset in echo requests)")
    ax.set_ylabel("Probability")
    ax.axvline(0, color='k', linewidth=0.8)
    leg = ax.legend(loc="lower right", fontsize=8, frameon=True)
    leg.get_frame().set_alpha(0.5)
plt.tight_layout()
```



1.6 Q6–7. Minimum and Maximum RTT over entire interval

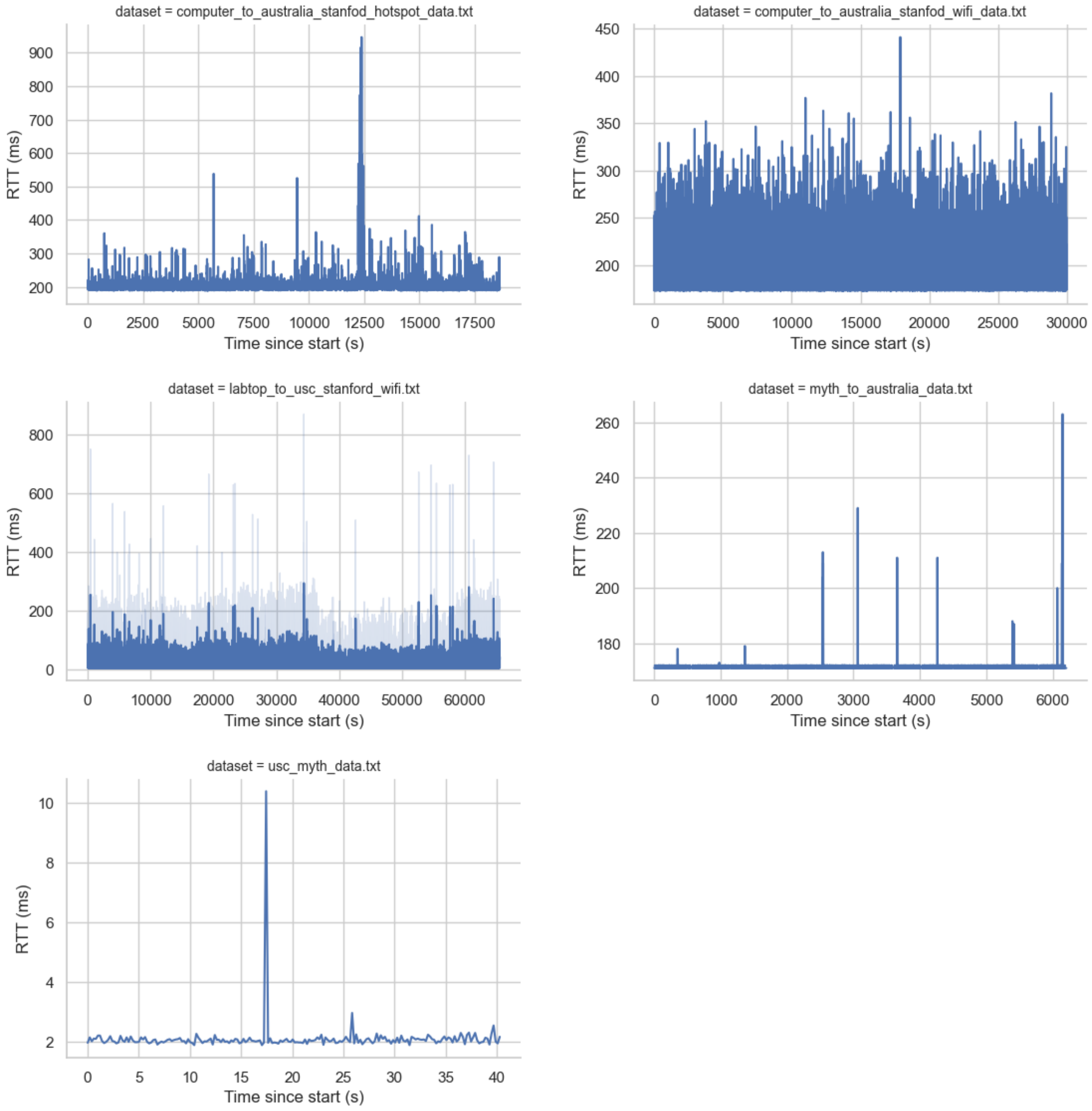
```
[11]: rtt_stats = (
          pings[pings["success"]]
              .groupby("dataset")["rtt_ms"]
              .agg(["count","min","max","median","mean"]).reset_index()
      )
      rtt_stats
```

```
[11]:                                          dataset   count      min       max  \
      0  computer_to_australia_stanfod_hotspot_data.txt   18637  187.707   946.772
      1     computer_to_australia_stanfod_wifi_data.txt   29969  172.424   441.142
      2               labtop_to_usc_stanford_wifi.txt  349552    3.659  1497.123
      3                    myth_to_australia_data.txt   30970  171.000   263.000
      4                             usc_myth_data.txt     202    1.890    10.400

          median        mean
      0  200.857  206.579507
      1  174.609  192.548481
      2    5.586   18.592425
      3  171.000  171.052793
      4    2.045    2.102921
```

1.7 Q8. Graph RTT as a function of time

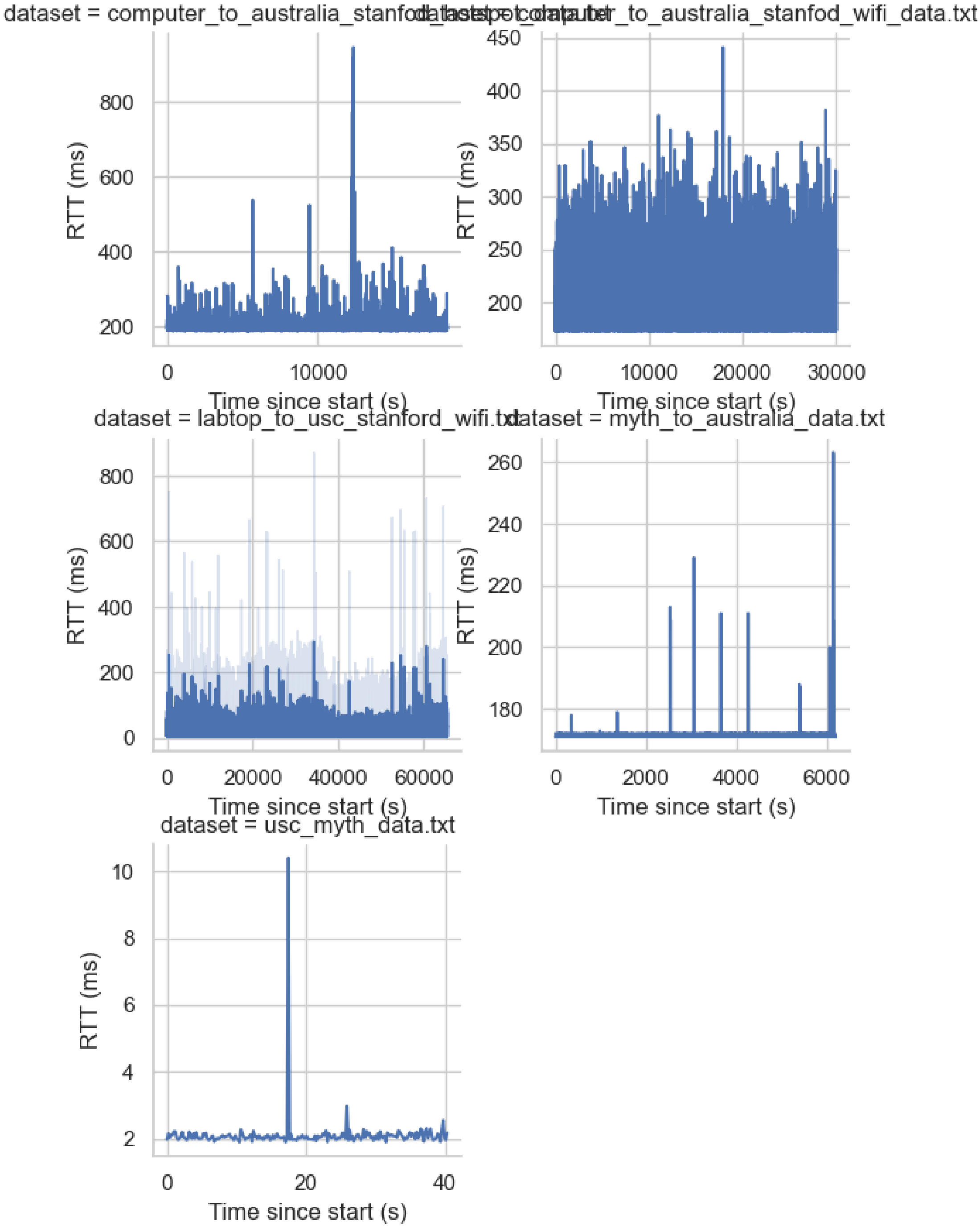
x-axis: actual time (approx from epoch when available, otherwise seq-based), y-axis: RTT (ms).

```
[12]: g = sns.relplot(
          data=pings[pings["success"]],
          x="t_sec", y="rtt_ms", col="dataset", kind="line",
          col_wrap=2, height=4, aspect=1.4,
          facet_kws=dict(sharex=False, sharey=False),
      )

      # Add axis labels per subplot
      for ax in g.axes.flatten():
          ax.set_xlabel("Time since start (s)")
          ax.set_ylabel("RTT (ms)")

      # Give more space between facets and top titles
      g.fig.subplots_adjust(top=0.92, wspace=0.25, hspace=0.35)

      # Make facet titles smaller and wrap if long
      for ax in g.axes.flatten():
          ax.set_title(ax.get_title(), fontsize=10)

      plt.show()
```



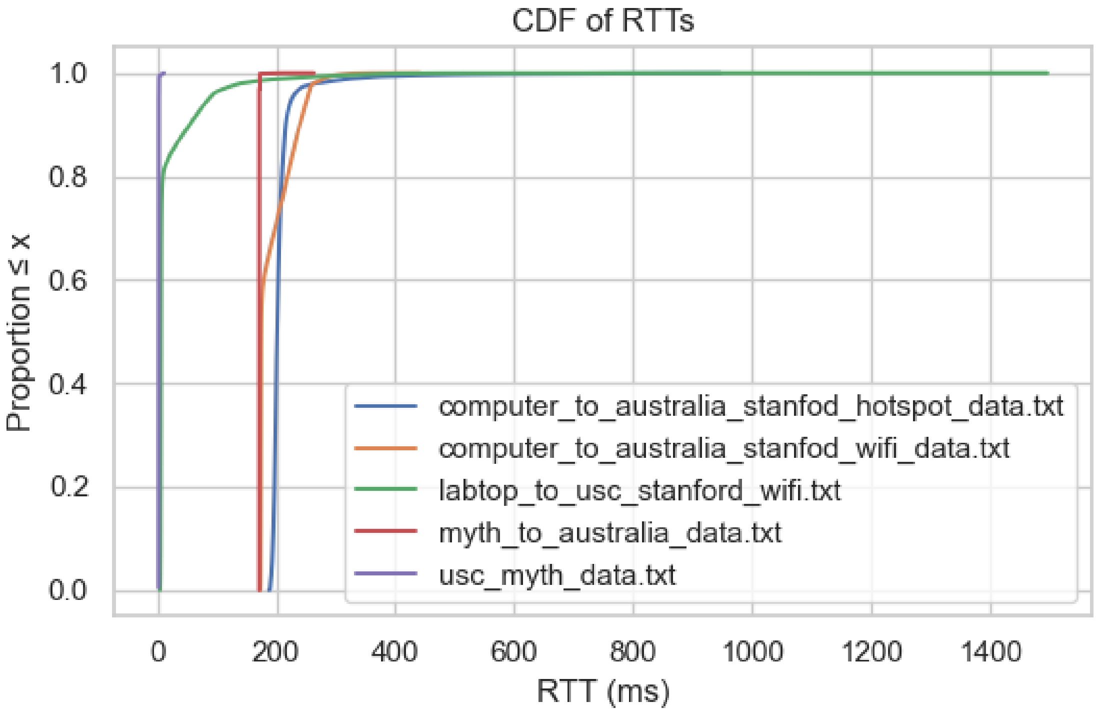
[13]:

```
g = sns.relplot(
    data=pings[pings["success"]],
    x="t_sec",
    y="rtt_ms",
    col="dataset",
    kind="line",
    col_wrap=2,
    height=3,
    facet_kws=dict(sharex=False, sharey=False)
)

for ax in g.axes.flatten():
    ax.set_xlabel("Time since start (s)")
    ax.set_ylabel("RTT (ms)")
plt.show()
```



1.8 Q9. CDF of RTTs

```
[14]: def plot_cdf(ax, data, label=None):
          x = np.sort(np.asarray(data))
          y = np.arange(1, len(x)+1) / len(x)
          ax.plot(x, y, label=label)

      fig, ax = plt.subplots(figsize=(6,4))
      for name, df in pings[pings["success"]].groupby("dataset"):
          plot_cdf(ax, df["rtt_ms"], label=name)
      ax.set_xlabel("RTT (ms)")
      ax.set_ylabel("Proportion   x")
      ax.set_title("CDF of RTTs")
      ax.legend()
      plt.tight_layout()
```



1.9 Q10. Scatter: RTT[N] vs RTT[N+1] and correlation

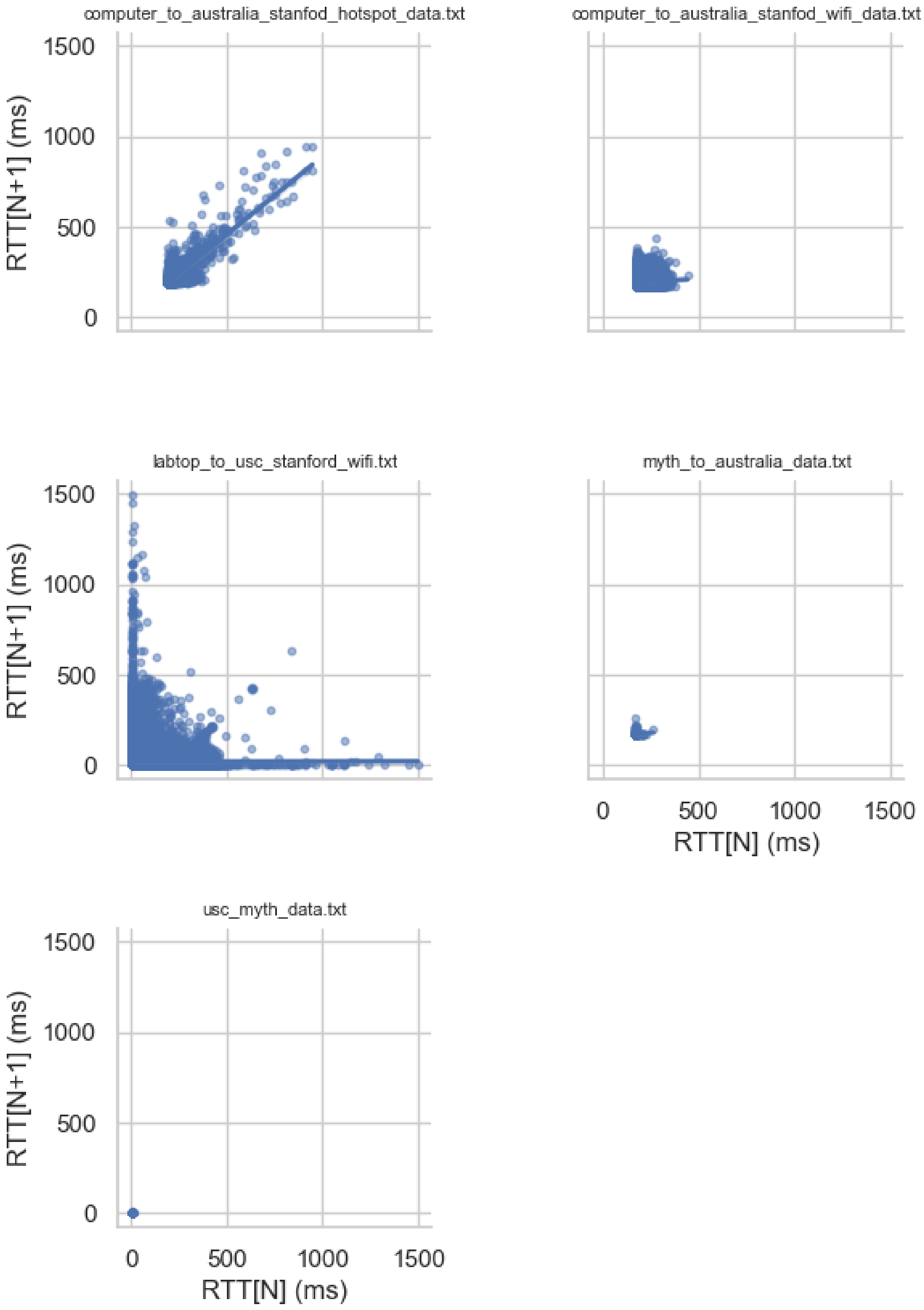
```
[15]: scatter_frames = []
      for name, df in pings[pings["success"]][["dataset","seq","rtt_ms"]].
       ↪groupby("dataset"):
          d = df.sort_values("seq").copy()
          d["rtt_next"] = d["rtt_ms"].shift(-1)
```

```
    scatter_frames.append(d)
scatter_df = pd.concat(scatter_frames).dropna(subset=["rtt_ms","rtt_next"])

# correlation per dataset
corrs = scatter_df.groupby("dataset").apply(lambda x: x[["rtt_ms","rtt_next"]].
 ↪corr().iloc[0,1]).rename("corr").reset_index()

# plot
g = sns.lmplot(data=scatter_df, x="rtt_ms", y="rtt_next", col="dataset",␣
 ↪col_wrap=2, height=3, scatter_kws=dict(s=10, alpha=0.5))
for ax in g.axes.flatten():
    ax.set_xlabel("RTT[N] (ms)")
    ax.set_ylabel("RTT[N+1] (ms)")

# Reduce title font size + add spacing between facet titles
g.set_titles(col_template="{col_name}", size=8)
# smaller title text
g.fig.subplots_adjust(top=0.90, wspace=0.5, hspace=0.5) # more breathing room

corrs
```

```
/var/folders/jl/kxty9ftx6jz4jnztx5wctvt40000gn/T/ipykernel_53835/272098926.py:9:
FutureWarning: DataFrameGroupBy.apply operated on the grouping columns. This
behavior is deprecated, and in a future version of pandas the grouping columns
will be excluded from the operation. Either pass `include_groups=False` to
exclude the groupings or explicitly select the grouping columns after groupby to
silence this warning.
  corrs = scatter_df.groupby("dataset").apply(lambda x:
x[["rtt_ms","rtt_next"]].corr().iloc[0,1]).rename("corr").reset_index()
```

[15]:

```
                                        dataset      corr
0  computer_to_australia_stanfod_hotspot_data.txt  0.859420
1     computer_to_australia_stanfod_wifi_data.txt  0.066485
2                 labtop_to_usc_stanford_wifi.txt  0.001903
3                      myth_to_australia_data.txt  0.104310
4                               usc_myth_data.txt -0.026345
```


computer_to_australia_stanfod_hotspot_data.txt
computer_to_australia_stanfod_wifi_data.txt
labtop_to_usc_stanford_wifi.txt
myth_to_australia_data.txt
usc_myth_data.txt
RTT[N+1] (ms)
RTT[N] (ms)
0
500
1000
1500

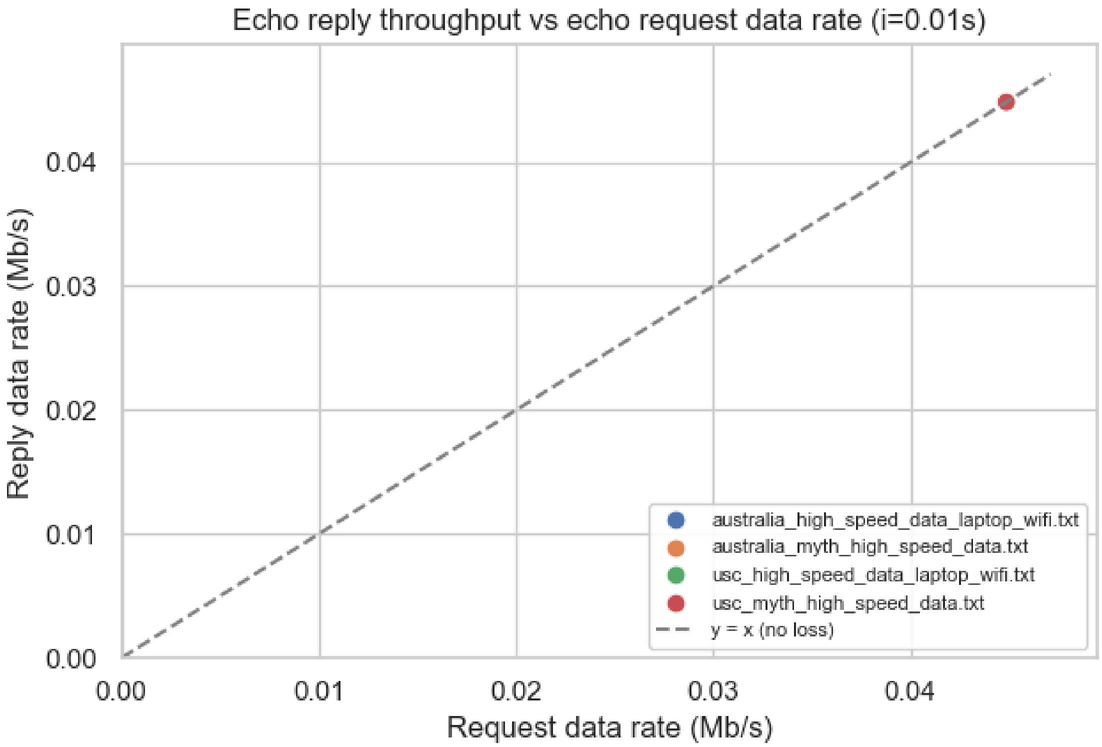
1.10 Q11. Throughput vs data rate experiments

We approximate data rate as `(packet_size × number_of_replies) / total_duration`. Since raw `-s`, `-i`, and `-c` settings aren't embedded, we infer per-file rate using observed replies and span of timestamps or sequence indices.

[16]:

```
# Q11 - High-rate experiments (interval = 0.01s)
HS_DIR = "/Users/nickallen/Documents/GitHub/CS144/data/high_speed_data"
HS_INTERVAL = 0.01

from glob import glob

HEADER_MAC_RE = re.compile(r"^PING .*: (?P<size>\d+) data bytes")
HEADER_LINUX_RE = re.compile(r"^PING .* (?P<size>\d+)\(\d+\) bytes of data\.$")

def infer_packet_size_bytes(path: str, default: int = 56) -> int:
    with open(path, "r", encoding="utf-8", errors="ignore") as f:
        for line in f:
            line = line.strip()
            if not line:
                continue
            m = HEADER_MAC_RE.match(line)
            if m:
                return int(m.group("size"))
            m = HEADER_LINUX_RE.match(line)
            if m:
                return int(m.group("size"))
            # stop early if we pass the header
            if line.startswith("64 bytes from") or "icmp_seq=" in line:
                break
    return default

hs_files = sorted(glob(os.path.join(HS_DIR, "*.txt")))
hs_rows = []
for pf in hs_files:
    df = parse_ping_file(pf)
    if df.empty:
        continue
    size_bytes = infer_packet_size_bytes(pf, default=56)
    seq_min, seq_max = int(df["seq"].min()), int(df["seq"].max())
    total_sent = seq_max - seq_min + 1
    # duration using known interval between requests
    duration_s = max((total_sent - 1) * HS_INTERVAL, 1e-6)
    replies = int(df["success"].sum())
    loss_rate = 1.0 - (replies / total_sent)
    # rates
    req_rate = total_sent / duration_s
    rep_rate = replies / duration_s
    req_bps = size_bytes * req_rate
    rep_bps = size_bytes * rep_rate
    hs_rows.append({
        "dataset": os.path.basename(pf),
        "packet_size_bytes": size_bytes,
        "total_sent": total_sent,
        "replies": replies,
        "loss_rate": loss_rate,
        "duration_s": duration_s,
        "requests_per_s": req_rate,
        "replies_per_s": rep_rate,
        "request_data_rate_Bps": req_bps,
        "reply_data_rate_Bps": rep_bps,
        "request_data_rate_Mbps": req_bps * 8 / 1e6,
        "reply_data_rate_Mbps": rep_bps * 8 / 1e6,
    })

hs_summary = pd.DataFrame(hs_rows).sort_values("dataset").reset_index(drop=True)
display(hs_summary)

# Plot reply data rate vs request data rate, with y=x reference
fig, ax = plt.subplots(figsize=(6.5, 4.5))
sns.scatterplot(
    data=hs_summary,
    x="request_data_rate_Mbps", y="reply_data_rate_Mbps",
    hue="dataset", s=60, ax=ax
)
max_x = hs_summary["request_data_rate_Mbps"].max() * 1.05
ax.plot([0, max_x], [0, max_x], linestyle="--", color="gray", label="y = x (no loss)")
ax.set_xlim(left=0)
ax.set_ylim(bottom=0)
ax.set_xlabel("Request data rate (Mb/s)")
ax.set_ylabel("Reply data rate (Mb/s)")
leg = ax.legend(loc="lower right", fontsize=8, frameon=True)
leg.get_frame().set_alpha(0.9)
ax.set_title("Echo reply throughput vs echo request data rate (i=0.01s)")
plt.tight_layout()
plt.show()

# Maximum throughput achieved
max_row = hs_summary.loc[hs_summary["reply_data_rate_Bps"].idxmax()]
print(
    f"Max reply throughput: {max_row['reply_data_rate_Mbps']:.2f} Mb/s "
    f"({max_row['reply_data_rate_Bps']:.0f} B/s) in {max_row['dataset']} "
    f"with packet size {max_row['packet_size_bytes']} bytes."
)
```

```
/var/folders/jl/kxty9ftx6jz4jnztx5wctvt40000gn/T/ipykernel_53835/3313088552.py:7
5: FutureWarning: Series.fillna with 'method' is deprecated and will raise in a
future version. Use obj.ffill() or obj.bfill() instead.
  df["t_sec"] = df["epoch_ts"].fillna(method="ffill").fillna(method="bfill") -
t0
/var/folders/jl/kxty9ftx6jz4jnztx5wctvt40000gn/T/ipykernel_53835/3313088552.py:7
5: FutureWarning: Series.fillna with 'method' is deprecated and will raise in a
future version. Use obj.ffill() or obj.bfill() instead.
  df["t_sec"] = df["epoch_ts"].fillna(method="ffill").fillna(method="bfill") -
t0

                                     dataset  packet_size_bytes  total_sent  \
0  australia_high_speed_data_laptop_wifi.txt                 56         689
1         australia_myth_high_speed_data.txt                 56         742
2        usc_high_speed_data_laptop_wifi.txt                 56         682
3               usc_myth_high_speed_data.txt                 56         847

   replies  loss_rate  duration_s  requests_per_s  replies_per_s  \
0      689        0.0        6.88      100.145349     100.145349
1      742        0.0        7.41      100.134953     100.134953
2      682        0.0        6.81      100.146843     100.146843
3      847        0.0        8.46      100.118203     100.118203

   request_data_rate_Bps  reply_data_rate_Bps  request_data_rate_Mbps  \
0            5608.139535          5608.139535                0.044865
1            5607.557355          5607.557355                0.044860
2            5608.223201          5608.223201                0.044866
3            5606.619385          5606.619385                0.044853

   reply_data_rate_Mbps
0              0.044865
1              0.044860
2              0.044866
3              0.044853
```



```
Max reply throughput: 0.04 Mb/s (5608 B/s) in
usc_high_speed_data_laptop_wifi.txt with packet size 56 bytes.
```

The data rate does not level out and was consistent through all tests.

1.11 Q12. Conclusions from the data

The differences between wired and unwired was super surprising. The wired myth test was almost always exaclty 171ms without much variance. This stayed consistent over the short distance to USC. It was super interesting to gain insight into the reliability of wifi by constrating it with the wired connection. It was also interesting to look at wifi versus cellular data. Australia transmission with wifi versus cellular, wifi was more consitent with lower RTTs than cellular showing it is more robust. What really surprised me was the amount of variance we saw when sending messages from Stanfrord wifi to USC. While this test was longer than others, there was far far worse preformance compared to the data transmissions on the wired machine to USC. Thus, I was surprised to learn overall that variance in the data transmission time can be attributed to the type of connection (wired / wireless). While actual base time is extremely closely tied with how far the package is actually traveling.

1.12 Q13. Interesting comparisons between paths and other network paths

In terms of difference between the paths, it was interesting to see that the first hop from laptop to australia and myth to australia were different. However, the both evenutally go through an address starting with 171.64 that is some kind of SUNET network. They also both leave Stanford in the same manner, hitting the 137.164.27.60 router. After this point, the path is the same, which makes sense that they both find the optimal path once a common node is reached. We saw similar behavoir with USC from myth versus wifi. They start off in different stanford networks but after the first hop after stanford they find the same path, which I would assume is the optimal path to the desitnation. Given that I ran these tests at different times, it is intersting that the congestion / network state at the time doesn't lead towards different optimal paths. There were also many entries with ***. I did not necessarily know if this was an explicit hop, or if the traceroute function couldn't read from these endpoints. I did not have a very good idea what to make of these lines and how to incorporate them into my analysis.