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Burst (of packets) and Burstiness

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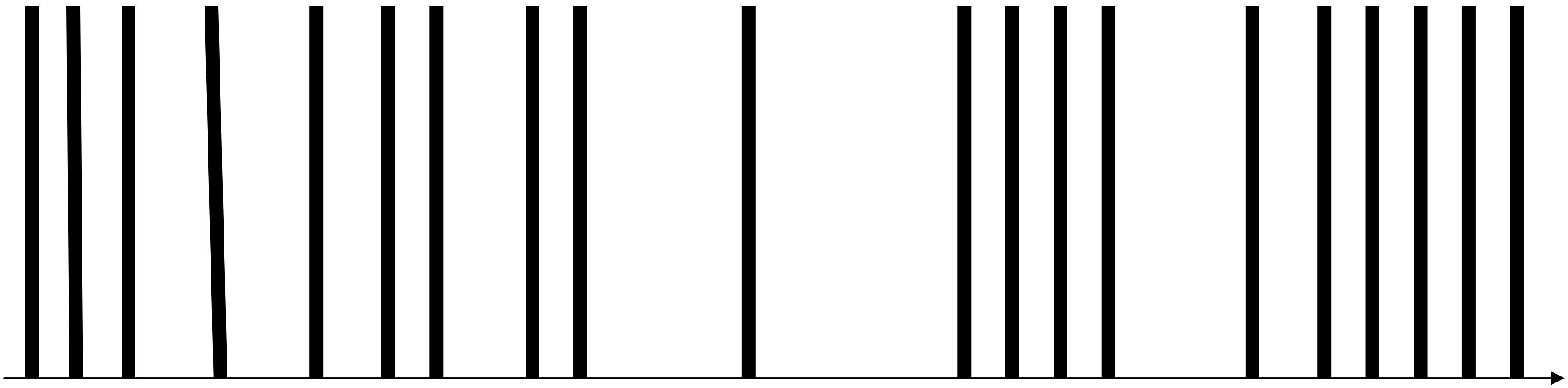
Outline

- Objectives
- Definition of a phenomena
- Definition of Burst and burstiness
- Future research
  - 2^{nd} order metrics of burstiness
  - 3^{rd} order metrics of burstiness
- References

Objectives

- Provide definition of
  - Burst (of packets)
  - Burstiness (of a flow of packets)
- Possible future extensions



Packet arrival time

- Packets in some applications are expected to arrive at specified times:
    - voip, video
    - PWE ATM /TDM
- Because of the network conditions (congestion, retransmissions, routing, buffering, protocol translation ->architecture- ToMPLS) packets do arrive clumped together
- The end system must be able to rearrange the packets into the expected application flow rates – arrival times to protect the application- as an application may not be able to deal with the packets arriving as variable rates
- With multiple flows and multiple applications in a packet stream packet arrival rates may also appear as bursts of packets
- There are multiple measures of business of flows, there is no a measure that is standardized and can be used for the comparative analysis of burstiness of flow
- The purpose of this proposal is to define a measure of burstiness that can be used as a metric for the burstiness of the flow or flows.

Burstiness – Problem Statement

- **Need to characterize burstiness of flows**
  - **Bursts influence network architectures**
    - Affect the protocol selection
      - ToMPLS – how ATM cells are encapsulated may affect the flow quality
    - Affect the requirements and functional specifications
      - For ATMoMPLS the type of ATM cell encapsulation
      - For TDMoMPLS the number of cells in the MPLS payload
  - **Need to define flow and application signatures based on burstiness**
    - Characterize applications
    - Simulate applications or traffic → need some operational metric of burstiness
  - **Bursts affect the network dimensioning**
    - QoS parameters must be configured to account for traffic bursts
      - CIR,PIR
      - Link dimensioning must account for traffic burstiness
    - End buffer parameters
      - End buffer must be dimensioned to account for bursts of packets

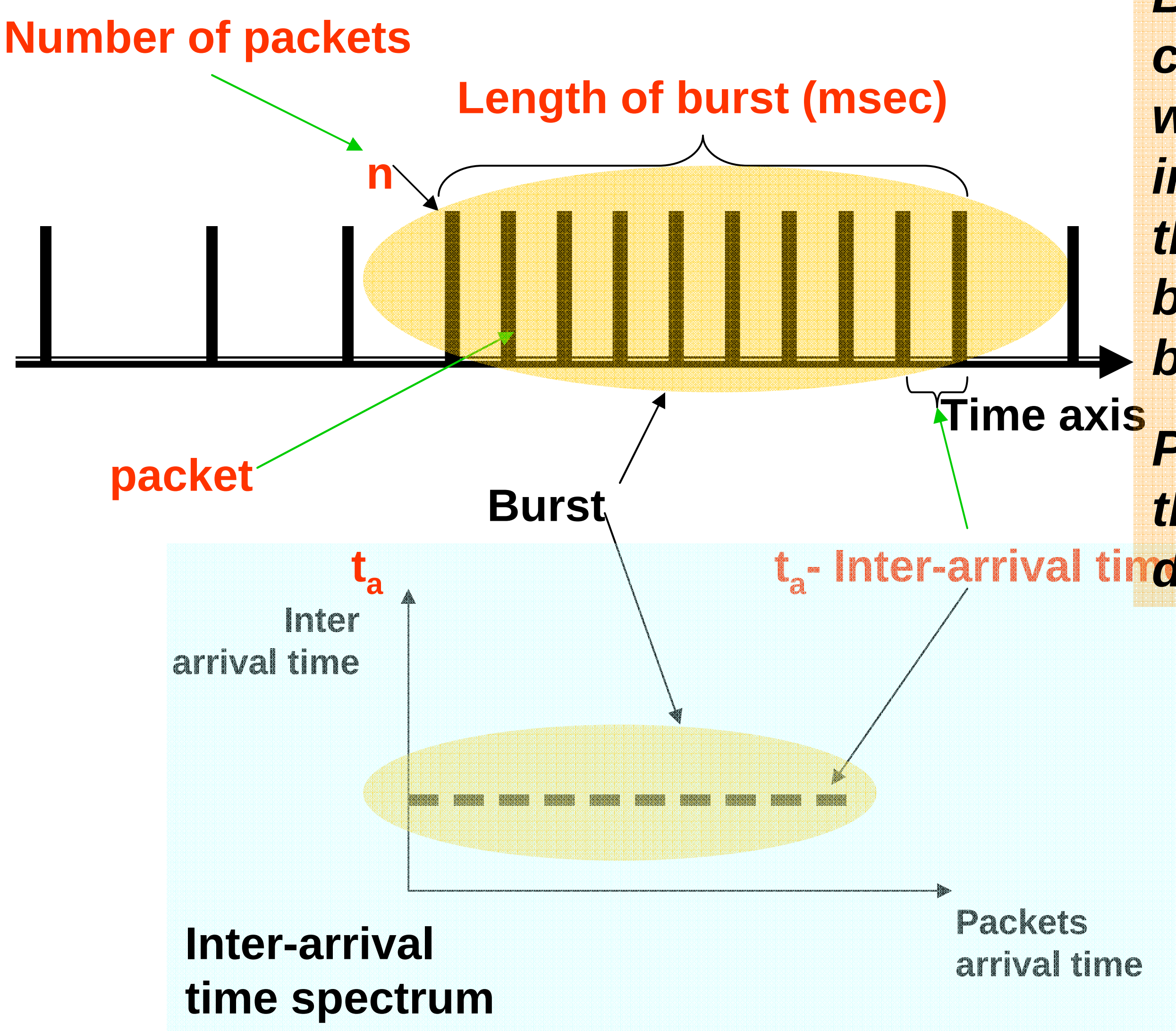
Burstiness – Problem

- **To accomplish this we need:**
  - **to characterize burst in the uniform comparable way**
    - » **Many measures exist**
  - **to have one common standard for describing burst characteristics of a flow**
    - » **Does not eliminate other metrics but provides means to provide measurements that can be compared**

- **Intuitive Definition**
  - ***Burst*** *is a group of consecutive packets with shorter interpacket gaps than packets arriving before or after the burst of packets.*
  - ***Burstiness*** *is a characterization of bursts in a flow over T.*

- We need a formal definition

Burst – reference model



Burst is a group of consecutive packets with shorter interpacket gaps than packets arriving before or after the burst of packets.

Packets maybe of the same flow or of different flows

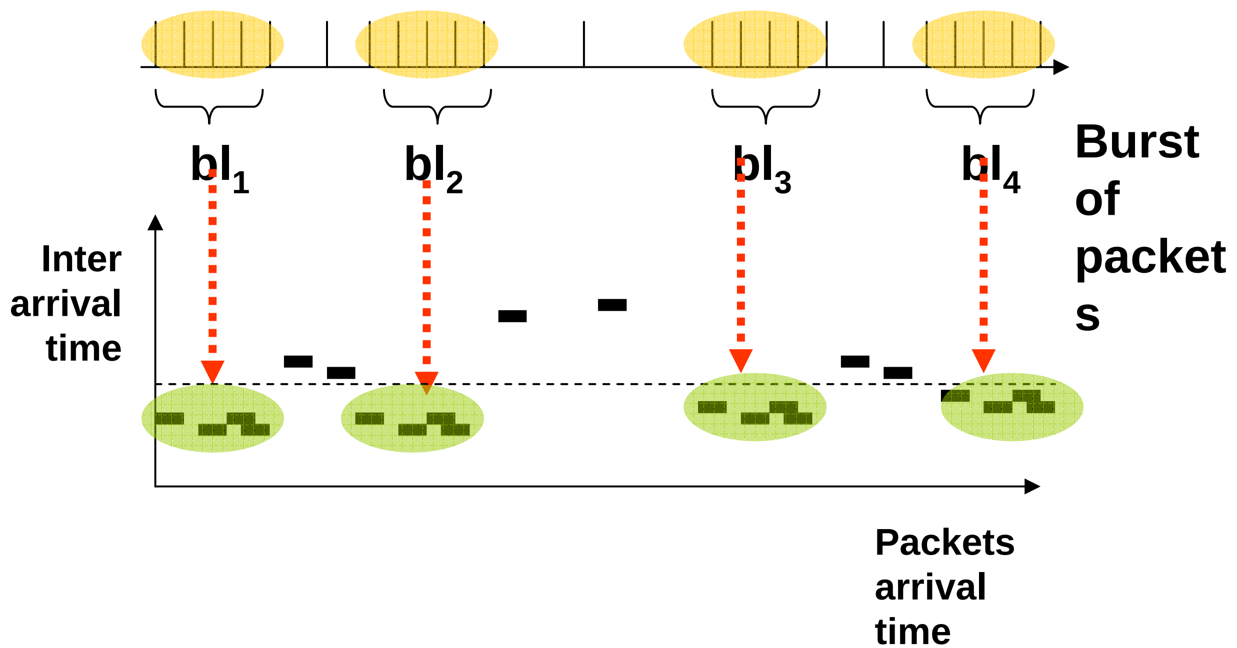
Burst (of packets)

- Burst – B=f(t, di)
  - **Burst – a sequence of consecutive packets whose inter-packet arrival time t_a is shorter than the interarrival time *of packets arriving before or after* these packets* and is in a range $(t_d\text{-}d_1,t+d_2)$ where d_i is a tolerance and t_d is a predefine interpacket arrival time. The interarrival time is counted from last bit of packet 1 to first bit of packet 2 .**
  - **Thus, consecutive packets form a burst if their interarrival times are t_a -> $\{t_d\text{-}d_1,td+d_2)$**
    - » **Where d_i is $\{0.00, t_d)$ and d_1 may not equal d_2**

  - **Burst parameters**
    - **t_a – inter-arrival time of packets in burst**
    - **d_{ta} – Inter-arrival time tolerance**
    - **p_i - a size of packet "I"**
  - **Depending on d_i we have options a,b,c**
    - **Option (a) If di > 0.0 and < t and d1= d2**
      - **We have a band tolerance**
    - **Option (b) If d1 ~ t and d2 = 0.0**
      - **We have a half-plane definition**
    - **Option (c.) Other combinations of parameters are possible**

* This part is to prevent the situation on slide 11

Packet Flow and Inter-arrival time Spectrum

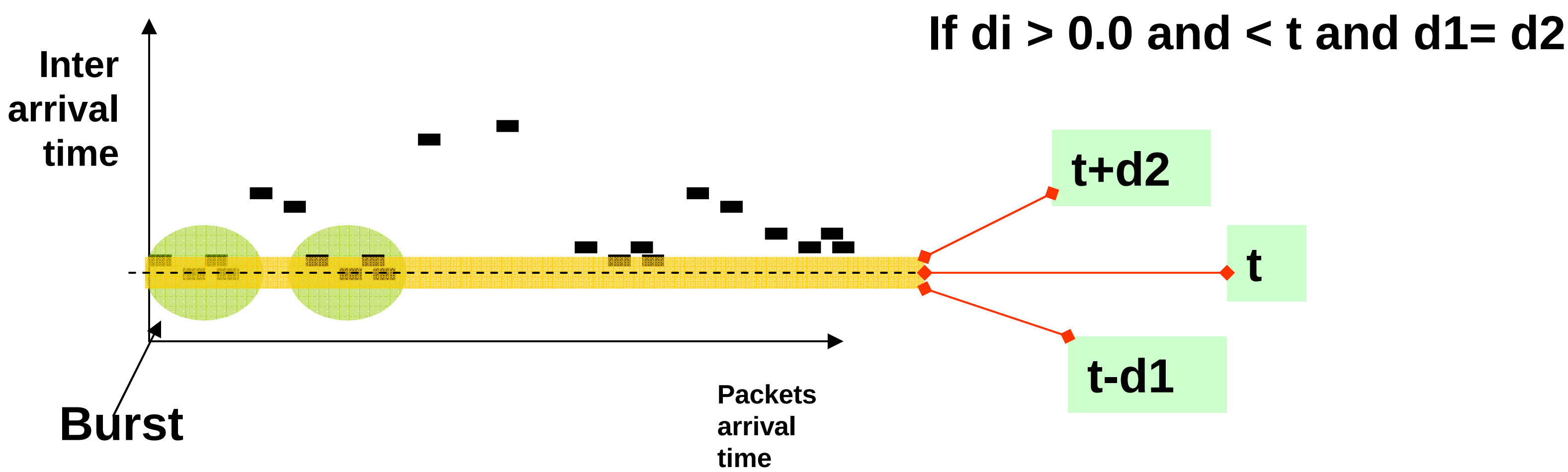


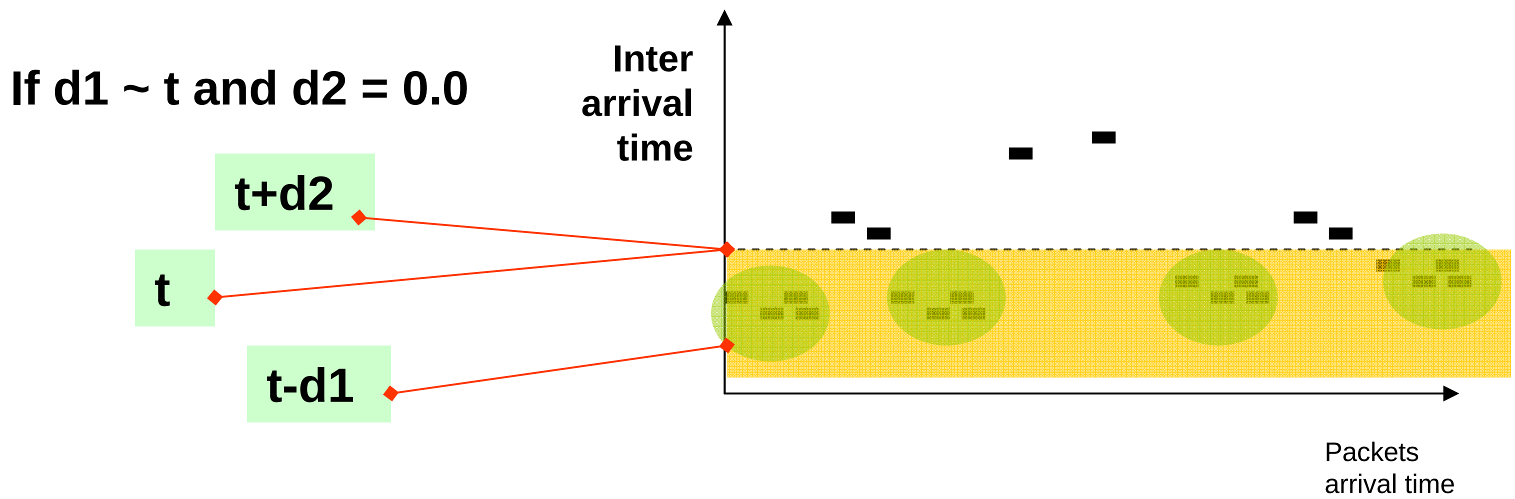
Spectrum is a 2-D function relating the packets arrival time (X axis) to the interpacket arrival gap (Y axis)

Thus, the 2D elements of the Spectrum function represent the interarrival time between a pair of packets

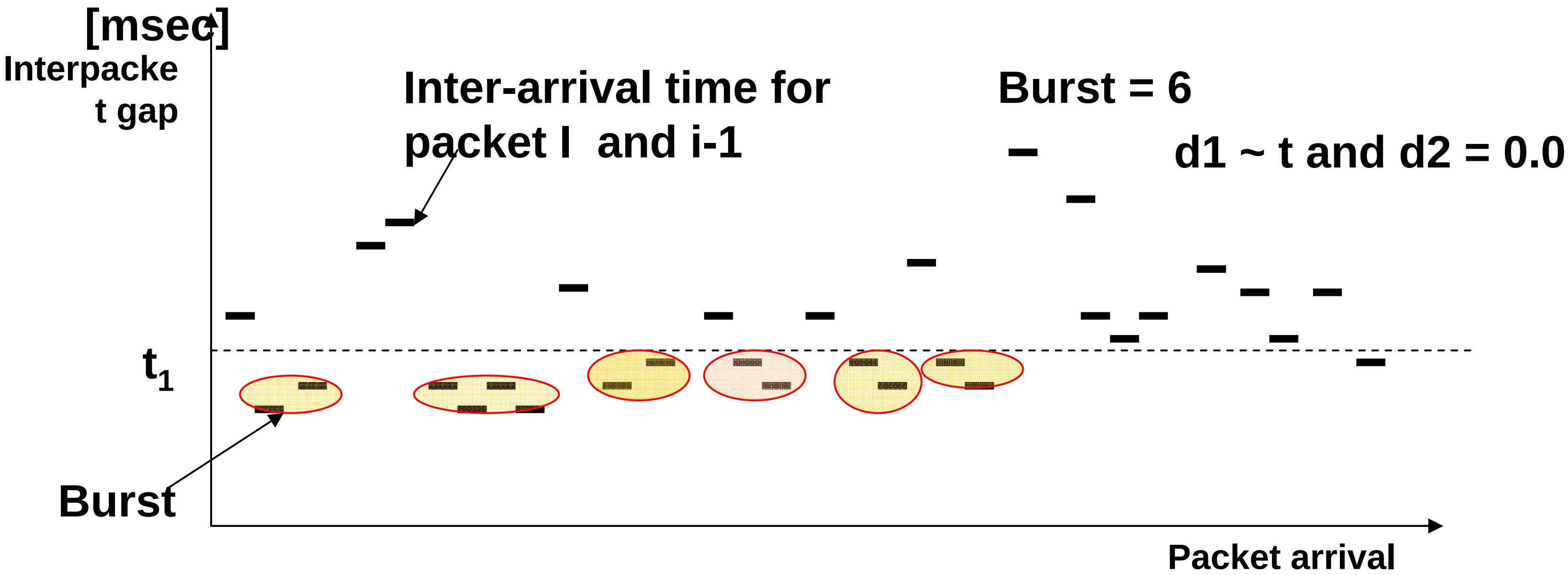
The function is used a s a convenient way to describe the packet flow interarrival times

Effect of burst definition



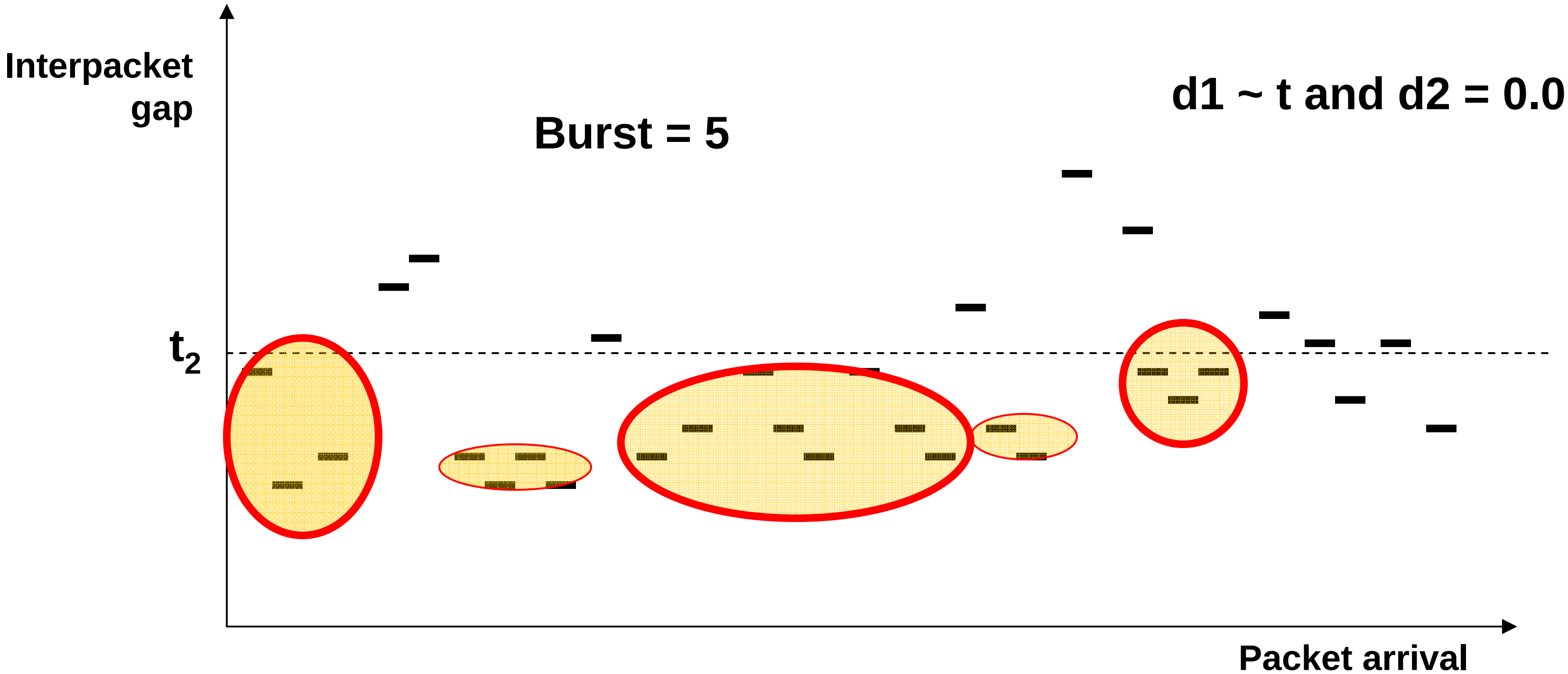


Effect of burst definition – A Case 1



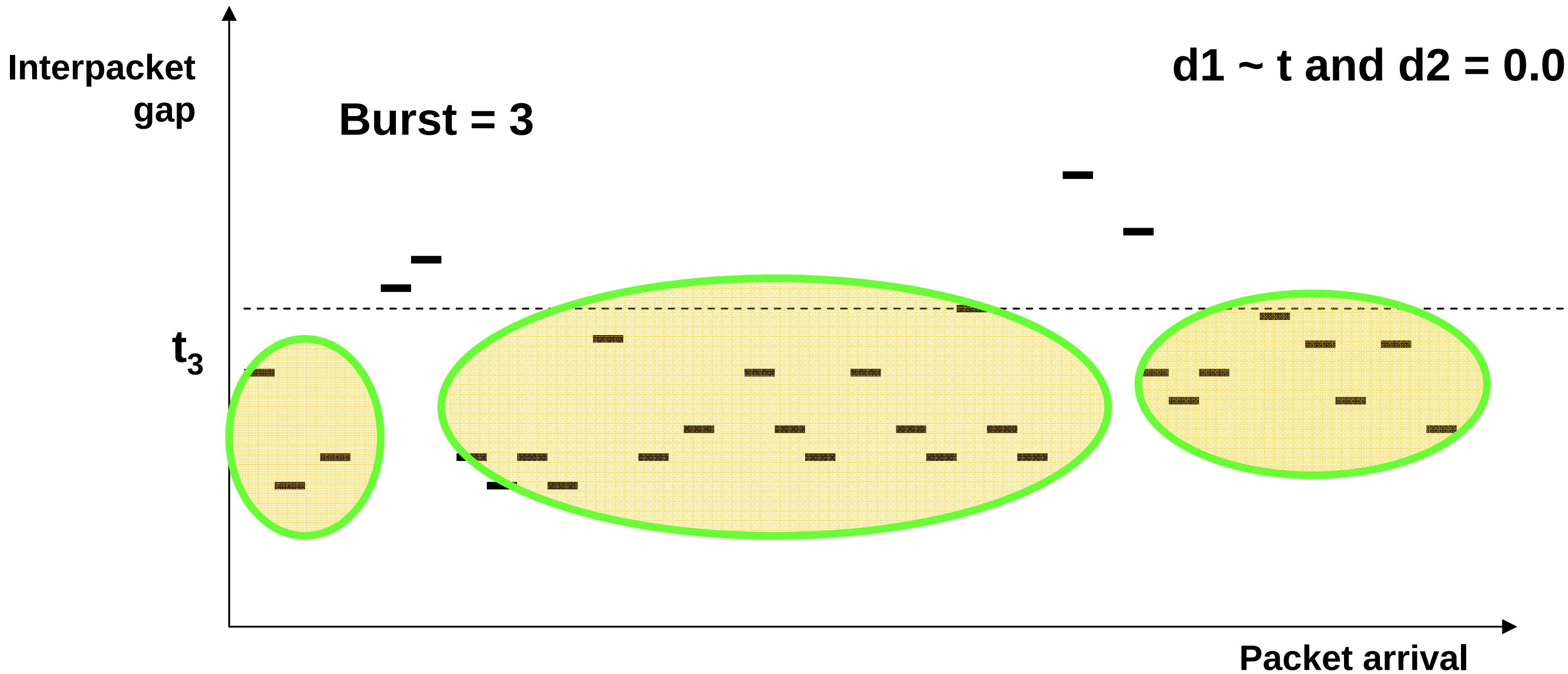
By setting the inter-arrival time at certain level we differentiate certain number of bursts.

Effect of burst definition- A Case 2



Changing the inter-arrival time we change the number and type of bursts

Effect of burst definition- A Case 3



Changing the inter-arrival time again we change the number and type of bursts

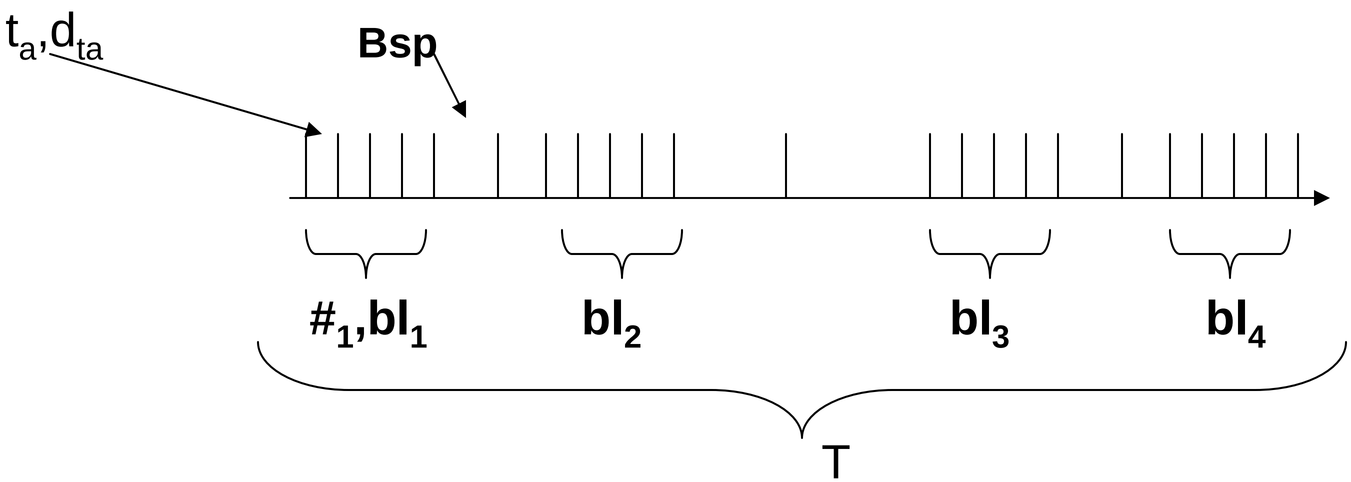
Burst metric

- This statistics describes a single burst <n,l,s>
  - Number of packets in Burst
    - n
      - Need to establish the min number of packets to be counter as burst, the absolute minimum is 2
  - Length of burst
    - l
      - in time
  - Size of burst
    - s
      - In bytes (const)
  - Packet size of packets in burst (Do we need this ?)
    - Min, max, average

Burstiness

- **Characterization of the packet stream expressed in terms of bursts**
  - Burstiness flow parameters
    - Reference time T
  - **First order statistics (t_a,=c; d_{ta}= c) – scalar values**
    - $t_{a,}$
    - d_{ta}
    - (#) Number of bursts ($t_{a,,}d_{ta}$) (# over T)
    - (Bsp) Burst separation (ave, min, max)
    - (Bsb) Burst size (ave, min, max) in bytes
    - (Bs#) Burst size in number of packets (ave, min, max)
    - (Bf) Burst frequency (# of burst / T)

Burstiness – reference model first order metric



t_a,	..
d_{ta}	..
(#)	4
(Bsp)	…
(Bsb)	…
(Bs#)	5
(Bf)	5/T

First order statistics

- First order statistics (t_a,=c; d_{ta}= c)
  - Characteristics of bursts in a flow over T for a specific <ta,da> – packet inter-arrival time
  - Represented as scalars
    - $t_{a,}$
      - Inter-arrival time
    - d_{ta}
      - Inter-arrival time tolerance
    - Number of bursts ($t_{a,}d_{ta}$,p=const)
      - Number of bursts in T
    - Burst separation
      - Separation of bursts in ts (msec)
        - » Aver, min, max
    - Burst size
      - Burst size in bytes
        - » (ave, min, max)
      - Burst size in number of packets
        - » Ave min, max
    - Burst frequency
      - Number of bursts per unit of time

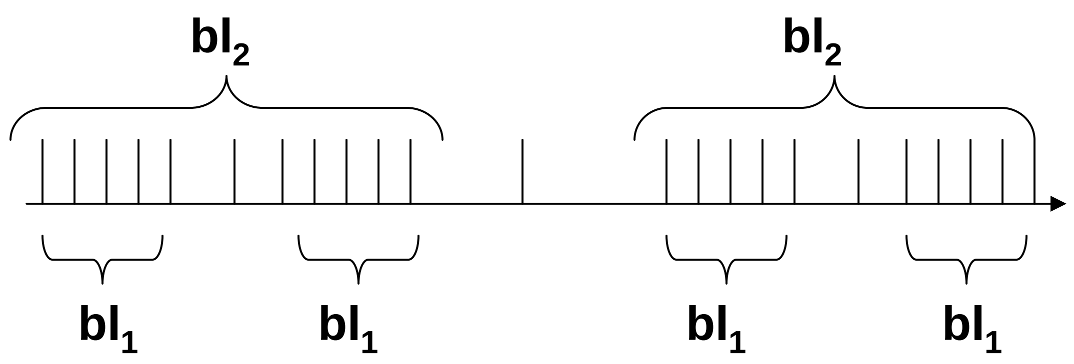
What are statistical properties of metrics with respect to the flow properties ?

Future Research

Burstiness 2nd and 3rd order stat

- Second Order Statistics ($t_{a,}$ d_{ta}) – 2-D or 3-D metrics composed of First order metrics (as planar cuts)
  - Number of bursts ($t_{a,}$ d_{ta})
  - Burst separation ($t_{a,}$ d_{ta})
  - Burst size (ave, min, max) ($t_{a,}$ d_{ta})
  - Burst frequency ($t_{a,}$ d_{ta})
- Third order statistics -
  - TBD
    - Complex metrics, density functions, FFT, …etc

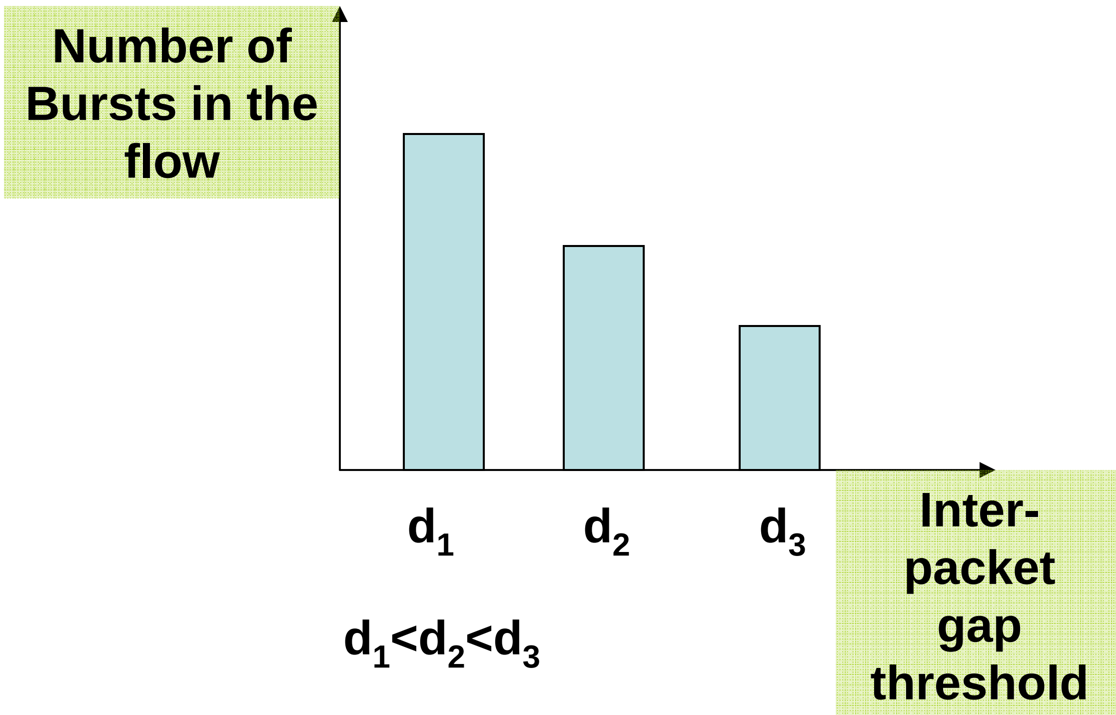
Burstiness – reference model second order metric



Second Order Statistics

- Second Order Statistics $(t_{a}, d_{ta} \neq c)$
  - Burst characteristics of a flow for a range of t, and d?
  - Represented as a 2-D or 3-D function
    - Number of bursts $(t_{a}, d_{ta} \neq c)$
      - Function expressing number of bursts $(t_{a}, d_{ta} \neq c)$ over T
    - Burst separation $(t_{a}, d_{ta} \neq c)$
      - Function expressing burst separation in sec of bursts of $(t_{a}, d_{ta} = c)$ over T
    - Burst size (ave, min, max) $(t_{a}, d_{ta} \neq c)$
      - Function expressing ave, min, max number of bursts of $(t_{a}, d_{ta} = c)$ over T in sec
      - Function expressing ave, min, max number of bursts of $(t_{a}, d_{ta} = c)$ over T in bytes
    - Burst frequency $(t_{a}, d_{ta} \neq c)$
      - Function expressing number of bursts of $(t_{a}, d_{ta} = c)$ over T per unit of time

Second Order Metrics



Third Order Statistics

- Concepts and examples
  - Varia
    - Peak to average bit rate ratio
    - Peak to average packet/frame ratio
  - Fractal measures
    - Hurst parameter
  - Model based statistics
    - One area that would be interesting to explore is to take an information theoretic approach to time varying metrics - using something along the lines of conditional entropy. In principle you could obtain a measure of the information content of a bursty stream of packets at source and compute the same measure at some other point, you would expect the metric to change as a result of per-packet changes in delay introduced by the network. This is just a rough idea however might be worth exploring. (Alan Clark)
    - Time series base models
    - FFT
    - Stationary random processes based models

Reference

- A Study of Burstiness in TCP Flows. Shakkotta, S. at el.
- MDI Media Delivery Index. Application Notes. Ineoquest. P.1-3, 2005