SWINBURNE

CENTRE FOR ADVANCED INTERNET ARCHITECTURES

A Theoretical Basis for Modelling Teletraffic Generated by First Person Shooter Games

Philip Branch

Outline

- Game traffic modelling
- Why a theoretical basis is needed
- A simple theoretical model
- Traffic profiles derived from theoretical model
- Comparison with real data
- Time series analysis
- Future work

First Person Shooter Games

- One of the most popular genres of games
- The most demanding in terms of QoS requirements
- Multiple players at diverse locations within the Internet
- Client Server architecture
- Interactions
  - Usually some kind of armed combat in a virtual world

Empirical modelling

- Collect traffic TCPdump traces
- Extract information about packet interarrival times and packet lengths from the server to the client and the client to the server
- Carry out statistical analyses to see what distribution best matches the data
  - Normal, Lognormal, Exponential, Impulse, Gamma
- See if there is any pattern across games and as the number of players increases

Quake3 and HalfLife empirical models

- Packet interarrival times from server to client
  - An Impulse distribution
- Packet interarrival times from the client to the server
  - An impulse with an exponential distribution
- Packet lengths from server to client
  - Lognormal distribution
- Packet lengths from client to server
  - Normal distribution

Generality of models

- Can empirical models be applied to other games?
  - We have models of Quake 3 and HalfLife. But there are lots of FPS games. Can a model of Quake 3 traffic tell us anything about other games such as Unreal Tournament or Day of Defeat?
  - Quake 3 and HalfLife have a common lineage. Maybe we would expect their traffic profiles to be similar.
  - Unreal tournament has a different lineage. Would we expect its traffic profile to be similar to Quake 3?

Generality of models

- Can empirical models be applied to larger numbers of players?
  - Detailed empirical models often usually obtained with a small (<10) players
  - Can they be generalised to large numbers of players?
  - If they can be generalised, how?

Why a theoretical basis is needed

- Limitations of empirical modelling
  - Cannot make any assertions as to generality of traffic models
  - Cannot make any assertions as to scalability of traffic models
- To generalise empirical models to larger numbers of players and other games we need some theory that explains the models

A simple model of game traffic

- What are the over-riding considerations when game designers develop a protocol for transmission of game state information between the server and the client?
- Some suggestions
  - Minimal bandwidth consumption
    - Want to reach as large a market as possible
    - Want to minimize problems of latency
  - Fairness
    - Want all players to be happy that their skill is the main criterion that affects their game playing performance

Consequences of assumptions

- Communication between the server and client will be in terms of minimal, bandwidth efficient codes, rather than video or animation sequences
  - Bandwidth assumption
  - Client software will interpret code-words and display appropriate animation on client screen
- Message rates from the server to the client will be approximately constant
  - Fairness assumption

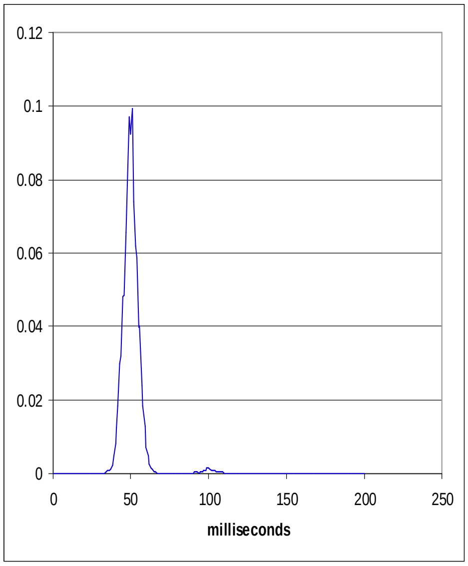
Message rates

- Message rates from server to clients
  - Would be frequent and close to constant
- Message rates from client to server
  - Would also be frequent and close to constant
- Would expect the Probability Density Function of interarrival times to be an impulse

CAIA seminar http://caia.swin.edu.au pbranch@swin.edu.au September 5, 2005 Page 11

Server to client interarrival time PDF

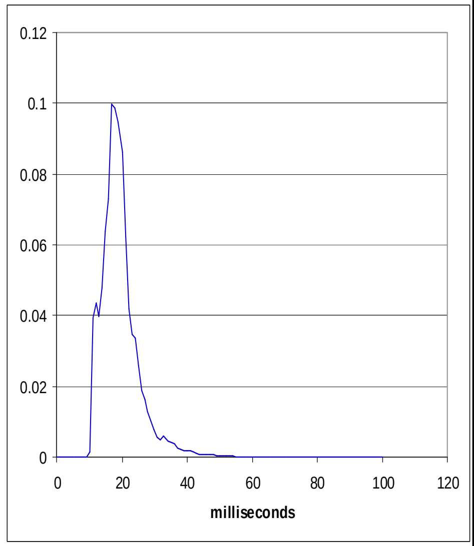
- Plot of interarrival time for Quake 3
- Similar plots for HalfLife
- Good approximation to an impulse



CAIA seminar http://caia.swin.edu.au pbranch@swin.edu.au September 5, 2005 Page 12

Client to server interarrival time PDF

- Plot of interarrival time for Quake 3
- Similar plots for HalfLife
- Reasonable approximation to an impulse
- Maximum interarrival time of about 50 milliseconds

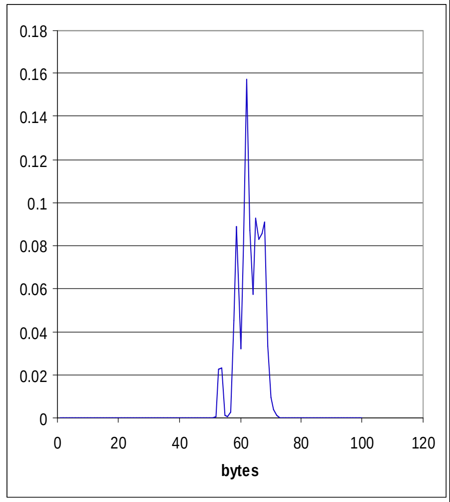


Client to Server packet lengths

- Some fixed component plus some variable component
- Fixed component would contain information about the game, the players etc.
- Variable component dependent on player action
  - eg. pickup grenade launcher, run, jump left
- Limited number of possible actions so limited number of packet lengths
  - Some action more common than others
- Would expect a number of impulses over a fixed range of lengths

Client to server packet lengths

- Plot of client to server packet length for Quake 3
- Similar plots for HalfLife
- Prediction is accurate
  - See a number of impulses between 50 and 70 bytes



CAIA seminar http://caia.swin.edu.au pbranch@swin.edu.au September 5, 2005 Page 15

Server to client message length model

- A few more assumptions
  - The same game-state model is transmitted to all players
    - Easy to code
    - Makes multicast possible
  - All players have similar behaviour
    - Not necessarily similar ability, but similar ratio of battle to non battle time
  - Player behaviour does not change as number of players increases

CAIA seminar http://caia.swin.edu.au pbranch@swin.edu.au September 5, 2005 Page 16

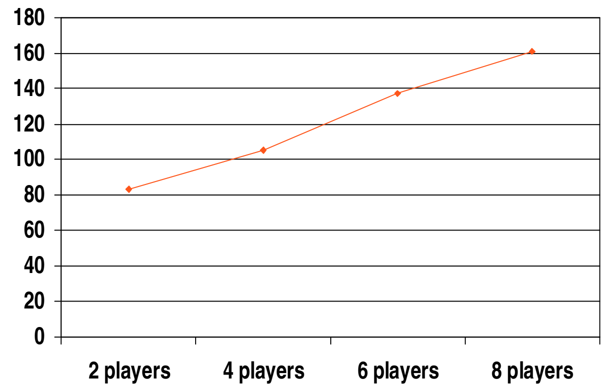
Server to client message length

- Message length will be made up of a constant length plus a variable component
  - Fixed component would contain information about the game
    - type of game, server etc
  - Variable component dependent on player actions
    - Code-words describing:
      - Individual player actions and their consequences
      - Player interactions

Server to client message length

- Average message length should increase as number of players increases
  - Game state made up of code-words that describe actions of players and their interactions
  - More players means that game-state contains more information so will increase
  - If we assume
    - all players have similar behaviour
    - behaviour of players does not change as the number of players increases,
  - Then the average increase in packet length as number of players increases should be linear

Server to client average message length

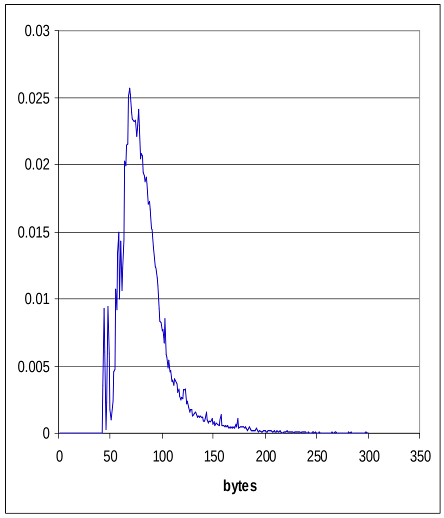


Server to client message length

- Message length PDF should be negatively skewed
  - Coded information is needed to describe interactions (battles)
  - Battles do not occur all the time
  - Consequently, long messages containing battle information will (on average) occur less frequently than short messages that do not contain battle information

Message length for two player game

- Quake 3 two player game
- Fixed component plus a variable component
- Skewed distribution



Can we predict message length PDF?

- Probability Density Function (PDF)
- If we know the PDF of a two player game, can we predict what a 4, 6, 8 etc player game will look like?
- Use the player behaviour assumptions
  - Players have similar behaviours
  - Player behaviour does not change dramatically as the number of players increase
    - Same ratio of battle to non-battle time
  - Each player interacts with (shoots at) other players at roughly the same rate regardless of the number of players

Some maths

Denote the variable part of the message length of a two player game by the random variable X and its PDF by F_X

Using the previous assumptions the message length of a four player game will be $X + X$.

The PDF of the sum of two or more games is their convolution *

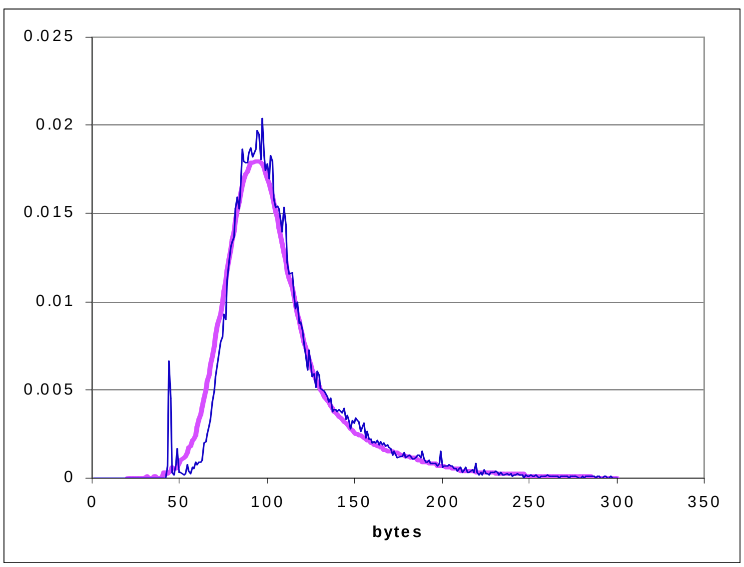
So the PDF of the variable part of the messages for four, six and eight player games will be:

F_{X+X} *(Four Player Game)* $= F_X * F_X$

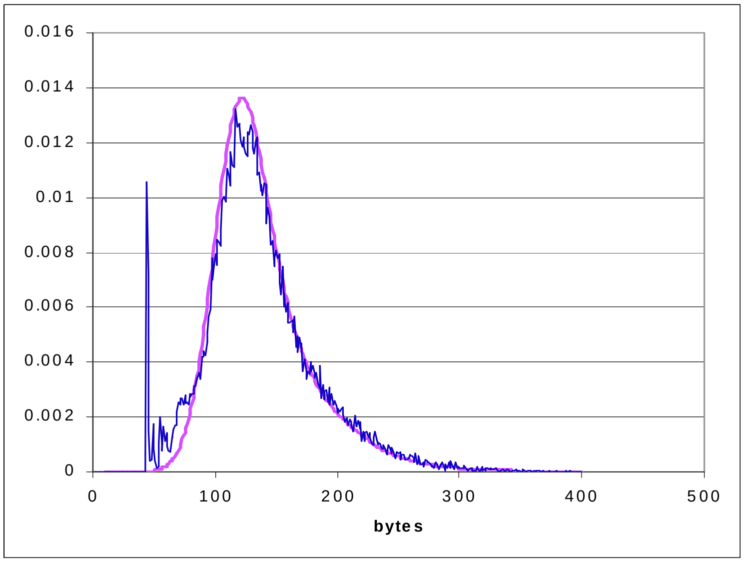
F_{X+X+X} *(Six Player Game)* $= F_X * F_X * F_X$

$F_{X+X+X+X}$ *(Eight Player Game)* $= F_X * F_X * F_X * F_X$.

Four player game

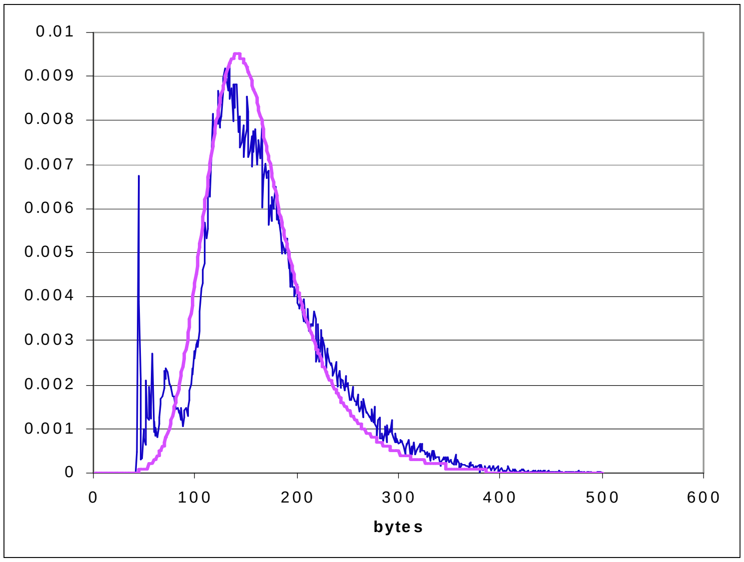


Six player game



CAIA seminar http://caia.swin.edu.au pbranch@swin.edu.au September 5, 2005 Page 25

Eight player game



CAIA seminar http://caia.swin.edu.au pbranch@swin.edu.au September 5, 2005 Page 26

Two player game

- We used the two player game PDF to derive approximations to 4, 6 and 8 player games
- Can we do anything similar to predict what a two player game might look like?
- We can speculate that it will consist of code-words specifying what the two clients have done plus some additional code-words specifying the consequences

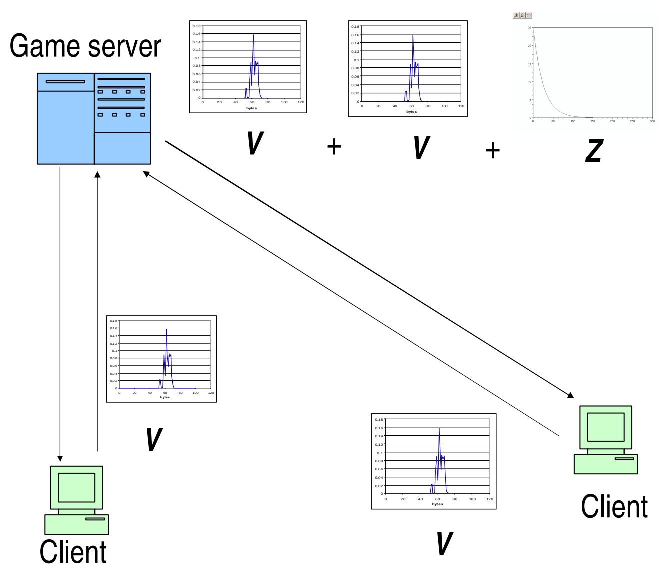
Some more maths

- Assume the variable part of messages from the server for a two player game are made up of the following components
  - Client to server codes for each player (Random variable *V*)
  - Additional codes describing consequences of player actions (Random variable *Z*)
- PDF of two player game will be
  - $F_V * F_V * F_Z$
- We have *V* from client to server PDF.
  - What about *Z*?

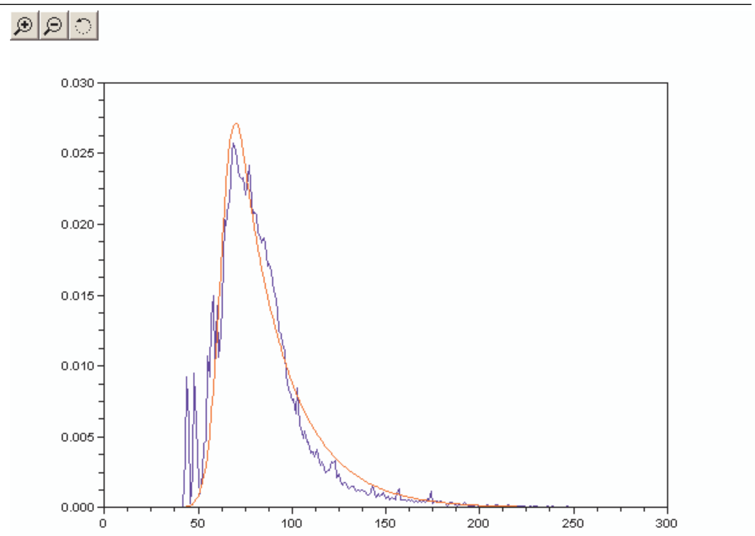
Some more maths

- Z will be negatively skewed
  - Consequence of efficient coding
  - Events requiring more code-words to describe them occur less frequently than other events
- Model Z with an exponential distribution
  - $F_z(t)=\lambda e^{-\lambda t}$ where $E(Z) = 1/\lambda$
- What value for λ (approximately)?
  - $E(X) = E(Z) + 2E(V)$
  - $E(X) = 47$, $E(V) = 11$ so $E(Z) = 1/\lambda = 25$
- So $F_z(t)=1/25\ e^{-t/25}$

Two player game



Two player game



Server to client packet length

- Used a few simple assumptions to construct a theoretical model of server to client packet length
  - Bandwidth assumption
  - Fairness assumption
  - Same game-state transmitted to all players
  - Players similar in behaviour
  - Player behaviour unaffected by number of players
- Theoretical model gives a good prediction of packet length characteristics
  - Knowing PDF of client to server traffic we can predict (surprisingly accurately) PDF of server to client traffic for multi-player games

Consequences

- Can predict the server traffic load for a large number of players for an FPS game if we know the behaviour of client to server traffic.
- Traffic seems quite predictable. No nasty fractal behaviour.
- However, aggregate traffic load on the server increases as the square of the number of players.
  - Average traffic load per player increases linearly with the number of players n.
  - So aggregate traffic load increases at the rate of n^2.

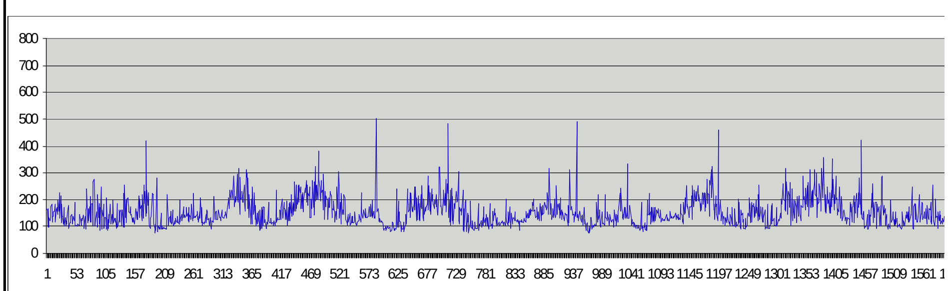
Time series analysis of game traffic

- Can we do a similar analysis on the time varying nature of game traffic behaviour?
- Yes, but it's much less interesting…
- Examine the time varying behaviour of server to client traffic
  - Autocorrelation function
    - The correlation of the function with itself for different lags
  - Fourier transform
    - Shows any periodic behaviour
  - Markov chain model of transitions
    - Shows any patterns in successive packet lengths

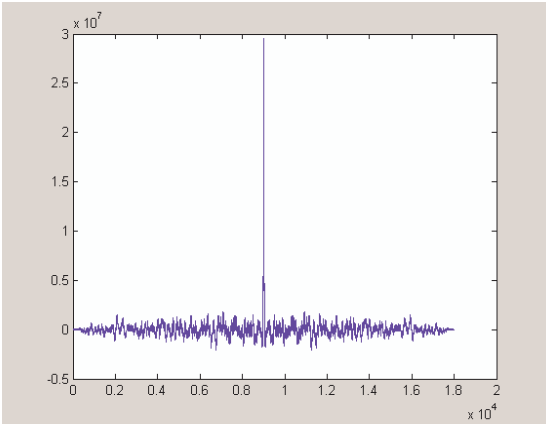
Model of time varying behaviour

- Would expect some correlation between activity levels
  - Battles would cause overall traffic rates to be high
  - Would expect periods of high activity followed by periods of lesser activity
  - What timescale?
    - Packet time?
    - Something longer?

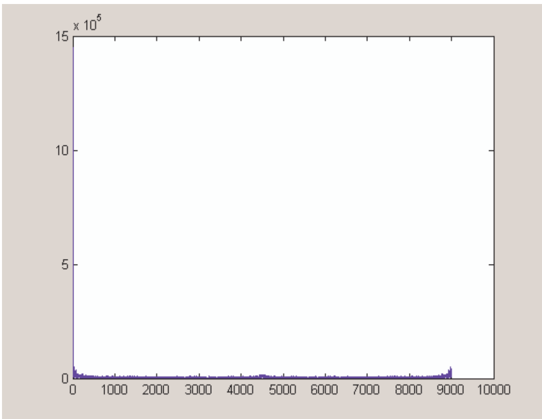
Time plot of packet length - four players



Autocorrelation function



Fourier transform



Time plot and autocorrelation function

- Fourier transform shows no periodic behaviour
- But time plot shows some cyclical behaviour
  - Seems to be sustained periods of activity interspersed with periods of lesser activity
- However, autocorrelation function shows no correlation between packet sizes
- Suggests that cyclical behaviour is not on packet timescale

Markov chain model

- Binned packet lengths into 50, 100, 150, 200, 250, 300, 350 and 400 byte lengths
- Analysed successive packet lengths to see the probability of a transition to another packet length, given the current packet length

Markov transition matrix (discrete time)

	50	100	150	200	250	300	350	400
50	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.37	0.46	0.13	0.04	0.01	0.00	0.00
150	0.00	0.07	0.55	0.26	0.09	0.03	0.00	0.00
200	0.00	0.04	0.40	0.34	0.15	0.05	0.01	0.00
250	0.00	0.01	0.31	0.36	0.20	0.08	0.03	0.02
300	0.00	0.01	0.23	0.32	0.22	0.12	0.07	0.03
350	0.00	0.01	0.15	0.26	0.27	0.11	0.07	0.13
400	0.00	0.02	0.20	0.18	0.22	0.14	0.06	0.19

Markov chain

- Some weak correlation between successive packet lengths?
- Maybe need to bin data over longer periods of time
  - Instead of 50 millisecond intervals maybe 500 millisecond intervals
- Needs more analysis and data…

Future work

- Traffic profiles of other FPS games?
  - Quake 3, HalfLife same lineage
  - What of games from a different lineage?
- Traffic profiles of other kinds of games?
  - Massively MultiPlayer Online Role Playing Games
- At what point and in what way do the assumptions of player behaviour break down?
- Need to be a bit more mathematically rigorous in describing model
- Time series analysis needs a lot of work

Conclusion

- Have proposed a simple theoretical model of FPS game traffic.
  - Made some assumptions as to how the game would be constructed.
  - Made some assumptions about player behaviour.
- Model has been successful in predicting characteristics of packet interarrival time and packet length.
- Still lots of work to do in applying the theory to other games and in time series analysis.