

Typed Nomadic Time

Andrew Hughes

<http://www.dcs.shef.ac.uk/~andrew>

Department of Computer Science
University of Sheffield

Theory SIG - 07/07/2006

Outline

1 Introduction

Outline

- 1 Introduction
- 2 Syntax

Outline

- 1 Introduction
- 2 Syntax
- 3 Semantics

Outline

- 1 Introduction
- 2 Syntax
- 3 Semantics
- 4 Types

Outline

- 1 Introduction
- 2 Syntax
- 3 Semantics
- 4 Types

- Local synchronization

- Local synchronization
- Global synchronization

- Local synchronization
- Global synchronization
- **Distribution**

- Local synchronization
- Global synchronization
- Distribution
- **Mobility**

Outline

- 1 Introduction
- 2 **Syntax**
- 3 Semantics
- 4 Types

TNT Syntax

Table: Syntax of TNT

$$\begin{aligned} \mathcal{E} &::= \mathbf{0} \mid \Omega \mid \Delta \mid \Delta_\sigma \mid \alpha.\mathcal{E} \mid \mathcal{E} + \mathcal{E} \mid \\ &\quad [\mathcal{E}]\sigma(\mathcal{E}) \mid [\bar{\mathcal{E}}]\sigma(\mathcal{E}) \mid (\mathcal{E} \mid \mathcal{E}) \mid \mu X.\mathcal{E} \mid X \mid \\ &\quad \mathcal{E} \setminus a \mid m[\mathcal{E}]_{\bar{\sigma}}^{\mathcal{E}} \mid \mathcal{M}.\mathcal{E} \\ \mathcal{M} &::= \textit{in } m \beta \mid \textit{out } m \beta \mid \textit{open } m \mid \bar{\textit{in}} \mid \bar{\textit{out}} \mid \bar{\textit{open}} \end{aligned}$$

TNT Syntax

Table: Syntax of TNT

$$\begin{aligned} \mathcal{E} ::= & \mathbf{0} \mid \Omega \mid \Delta \mid \Delta_\sigma \mid \alpha.\mathcal{E} \mid \mathcal{E} + \mathcal{E} \mid \\ & [\mathcal{E}]\sigma(\mathcal{E}) \mid [\mathcal{E}]\sigma(\mathcal{E}) \mid (\mathcal{E} \mid \mathcal{E}) \mid \mu X.\mathcal{E} \mid X \mid \\ & \mathcal{E} \setminus a \mid m[\mathcal{E}]_\sigma^\mathcal{E} \mid \mathcal{M}.\mathcal{E} \\ \mathcal{M} ::= & \text{in } m \beta \mid \text{out } m \beta \mid \text{open } m \mid \overline{\text{in}} \mid \overline{\text{out}} \mid \overline{\text{open}} \end{aligned}$$

TNT Syntax

Table: Syntax of TNT

$$\begin{aligned} \mathcal{E} &::= \mathbf{0} \mid \Omega \mid \Delta \mid \Delta_\sigma \mid \alpha.\mathcal{E} \mid \mathcal{E} + \mathcal{E} \mid \\ &\quad [\mathcal{E}]\sigma(\mathcal{E}) \mid [\mathcal{E}]\sigma(\mathcal{E}) \mid (\mathcal{E} \mid \mathcal{E}) \mid \mu X.\mathcal{E} \mid X \mid \\ &\quad \mathcal{E} \setminus a \mid m[\mathcal{E}]_\sigma^\mathcal{E} \mid \mathcal{M}.\mathcal{E} \\ \mathcal{M} &::= \textit{in } m \beta \mid \textit{out } m \beta \mid \textit{open } m \mid \overline{\textit{in}} \mid \overline{\textit{out}} \mid \overline{\textit{open}} \end{aligned}$$

TNT Syntax

Table: Syntax of TNT

$$\begin{aligned} \mathcal{E} &::= \mathbf{0} \mid \Omega \mid \Delta \mid \Delta_\sigma \mid \alpha.\mathcal{E} \mid \mathcal{E} + \mathcal{E} \mid \\ &\quad [\mathcal{E}]\sigma(\mathcal{E}) \mid [\bar{\mathcal{E}}]\sigma(\mathcal{E}) \mid (\mathcal{E} \mid \mathcal{E}) \mid \mu X.\mathcal{E} \mid X \mid \\ &\quad \mathcal{E} \setminus a \mid m[\mathcal{E}]_{\bar{\sigma}}^{\mathcal{E}} \mid \mathcal{M}.\mathcal{E} \\ \mathcal{M} &::= \textit{in } m \beta \mid \textit{out } m \beta \mid \textit{open } m \mid \bar{\textit{in}} \mid \bar{\textit{out}} \mid \bar{\textit{open}} \end{aligned}$$

TNT Syntax

Table: Syntax of TNT

$$\begin{aligned} \mathcal{E} &::= \mathbf{0} \mid \Omega \mid \Delta \mid \Delta_\sigma \mid \alpha.\mathcal{E} \mid \mathcal{E} + \mathcal{E} \mid \\ &\quad [\mathcal{E}]\sigma(\mathcal{E}) \mid [\overline{\mathcal{E}}]\sigma(\mathcal{E}) \mid (\mathcal{E} \mid \mathcal{E}) \mid \mu X.\mathcal{E} \mid X \mid \\ &\quad \mathcal{E} \setminus a \mid m[\mathcal{E}]_\sigma^\mathcal{E} \mid \mathcal{M}.\mathcal{E} \\ \mathcal{M} &::= \textit{in } m \beta \mid \textit{out } m \beta \mid \textit{open } m \mid \overline{\textit{in}} \mid \overline{\textit{out}} \mid \overline{\textit{open}} \end{aligned}$$

Outline

- 1 Introduction
- 2 Syntax
- 3 Semantics**
- 4 Types

TNT Semantics: Idle

$$\frac{\text{—}}{\mathbf{0} \xrightarrow{\sigma} \mathbf{0}}$$

TNT Semantics: Act

$$\frac{-}{\alpha.E \xrightarrow{\alpha} E}$$

TNT Semantics: Patient

$$\frac{\text{—}}{a.E \xrightarrow{\sigma} a.E}$$

TNT Semantics: Stall

$$\frac{\text{—}}{\Delta_{\sigma} \xrightarrow{\rho} \Delta_{\sigma}} \rho \neq \sigma$$

TNT Semantics: Sum1

$$\frac{E \xrightarrow{\alpha} E'}{E + F \xrightarrow{\alpha} E'}$$

TNT Semantics: Sum2

$$\frac{F \xrightarrow{\alpha} F'}{E + F \xrightarrow{\alpha} F'}$$

TNT Semantics: Sum3

$$\frac{E \xrightarrow{\sigma} E', F \xrightarrow{\sigma} F'}{E + F \xrightarrow{\sigma} E' + F'}$$

TNT Semantics: Par1

$$\frac{E \xrightarrow{\alpha} E'}{E \mid F \xrightarrow{\alpha} E' \mid F}$$

TNT Semantics: Par2

$$\frac{F \xrightarrow{\alpha} F'}{E \mid F \xrightarrow{\alpha} E \mid F'}$$

TNT Semantics: Par3

$$\frac{E \xrightarrow{a} E', F \xrightarrow{\bar{a}} F'}{E \mid F \xrightarrow{\tau} E' \mid F'}$$

TNT Semantics: Par4

$$\frac{E \xrightarrow{\sigma} E', F \xrightarrow{\sigma} F', E \mid F \not\xrightarrow{\tau}}{E \mid F \xrightarrow{\sigma} E' \mid F'}$$

TNT Semantics: FTO1

$$\frac{E \xrightarrow{\tau} \text{---}}{[E] \sigma(F) \xrightarrow{\sigma} F}$$

TNT Semantics: FTO2

$$\frac{E \xrightarrow{\gamma} E'}{[E]_{\sigma}(F) \xrightarrow{\gamma} E'} \quad \gamma \neq \sigma$$

TNT Semantics: ST01

$$\frac{E \xrightarrow{\tau} \text{---}}{\llbracket E \rrbracket \sigma(F) \xrightarrow{\sigma} F}$$

TNT Semantics: ST02

$$\frac{E \xrightarrow{\alpha} E'}{\llbracket E \rrbracket \sigma(F) \xrightarrow{\alpha} E'}$$

TNT Semantics: STO3

$$\frac{E \xrightarrow{\rho} E'}{[E]_{\sigma}(F) \xrightarrow{\rho} [E']_{\sigma}(F)} \quad \rho \neq \sigma$$

TNT Semantics: Rec

$$\frac{E \xrightarrow{\gamma} E'}{\mu X.E \xrightarrow{\gamma} E' \{ \mu X.E / X \}}$$

TNT Semantics: Res

$$\frac{E \xrightarrow{\gamma} E'}{E \setminus a \xrightarrow{\gamma} E' \setminus a} \quad \gamma \neq a$$

TNT Semantics: Res

$$\frac{E \xrightarrow{\gamma} E'}{E \setminus a \xrightarrow{\gamma} E' \setminus a} \quad \gamma \neq a$$

TNT Semantics: LHd1

$$\frac{E \xrightarrow{\sigma} E'}{m[E]_{\vec{\sigma}}^B \xrightarrow{\tau} m[E']_{\vec{\sigma}}^B} \sigma \in \vec{\sigma}$$

TNT Semantics: LHd2

$$\frac{E \xrightarrow{\alpha} E'}{m[E]_{\vec{\sigma}} B \xrightarrow{\alpha} m[E']_{\vec{\sigma}} B}$$

TNT Semantics: LHd3

$$\frac{E \xrightarrow{\rho} E', E \xrightarrow{\sigma} \text{---}}{m[E]_{\vec{\sigma}}^B \xrightarrow{\rho} m[E']_{\vec{\sigma}}^B} \rho \ni \vec{\sigma}, \sigma \in \vec{\sigma}$$

TNT Semantics: Cap

$$\frac{}{\mathcal{M}.E \xrightarrow{\mathcal{M}} E}$$

TNT Semantics: InAmb

$$\frac{E \xrightarrow{in\ m\ \uparrow} E', B_1 \xrightarrow{\overline{out}} B'_1, B_2 \xrightarrow{\overline{in}} B'_2}{p[n[E \mid F]_{\vec{\sigma}}^{B_3} \mid m[G]_{\vec{\rho}}^{B_2}]_{\vec{\gamma}}^{B_1} \xrightarrow{\tau} p[m[G \mid n[E \mid F]_{\vec{\sigma}}^{B_3}]_{\vec{\rho}}^{B'_2}]_{\vec{\gamma}}^{B'_1}}$$

TNT Semantics: OutAmb

$$\frac{E \xrightarrow{out\ m\ \uparrow} E', B_1 \xrightarrow{\bar{in}} B'_1, B_2 \xrightarrow{\overline{out}} B'_2}{\rho[m[G \mid n[E \mid F]_{\vec{\sigma}}^{B_3}]_{\vec{\rho}}^{B_2}]_{\vec{\gamma}}^{B_1} \xrightarrow{\tau} \rho[n[E \mid F]_{\vec{\sigma}}^{B_3} \mid m[G]_{\vec{\rho}}^{B'_2}]_{\vec{\gamma}}^{B'_1}}$$

TNT Semantics: Open

$$\frac{E \xrightarrow{\text{open } m} E', B_1 \xrightarrow{\overline{\text{open}}} B'_1}{n[E \mid m[F]_{\vec{\sigma}}]_{\vec{\gamma}}^{B_2} \xrightarrow{\tau} n[E' \mid F]_{\vec{\gamma} \cup \vec{\sigma}}^{B_2}}$$

TNT Semantics: InProc

$$\frac{E \xrightarrow{a} E', F \xrightarrow{in\ m\ a} F', B_1 \xrightarrow{\overline{out}} B'_1, B_2 \xrightarrow{\overline{in}} B'_2}{n[((E \mid G) \setminus \vec{b}) \mid F \mid m[H]_{\vec{\sigma}}^{B_2}]_{\vec{\rho}}^{B_1} \xrightarrow{\tau} n[(G \setminus \vec{b}) \mid F' \mid m[H \mid (E' \setminus \vec{b})]_{\vec{\rho}}^{B'_2}]_{\vec{\sigma}}^{B'_1}}$$

TNT Semantics: OutProc

$$\frac{E \xrightarrow{a} E', F \xrightarrow{out} F', B_1 \xrightarrow{\bar{in}} B'_1, B_2 \xrightarrow{\bar{out}} B'_2}{n[H \mid m[((E \mid G) \setminus \vec{b}) \mid F]_{\vec{\sigma}}^{B_2}]_{\vec{\rho}}^{B_1} \xrightarrow{\tau} n[H \mid (E \setminus \vec{b}) \mid m[(G \setminus \vec{b}) \mid F']_{\vec{\sigma}}^{B'_2}]_{\vec{\rho}}^{B'_1}]}$$

Outline

- 1 Introduction
- 2 Syntax
- 3 Semantics
- 4 **Types**

TNT Types: Env

$$\frac{\xi : T \in \Gamma}{\Gamma \vdash \xi : T}$$

TNT Types: Nil

$$\frac{}{\Gamma \vdash \mathbf{0} : Proc(g)}$$

TNT Types: BNil

$$\frac{}{\Gamma \vdash \Omega : \mathit{BProc}}$$

TNT Types: Stop

$$\frac{}{\Gamma \vdash \Delta : Proc(g)}$$

TNT Types: Stall

$$\frac{\Gamma \vdash \sigma : \mathit{Clock}}{\Gamma \vdash \Delta_{\sigma} : \mathit{Proc}(g)}$$

TNT Types: Act

$$\frac{\Gamma \vdash \alpha : \mathit{Act}, \Gamma \vdash P : \mathit{Proc}(g)}{\Gamma \vdash \alpha.P : \mathit{Proc}(g)}$$

TNT Types: Sum

$$\frac{\Gamma_1 \vdash P : Proc(g), \Gamma_2 \vdash Q : Proc(g), \Gamma_1 \# \Gamma_2}{\Gamma_1 \cup \Gamma_2 \vdash P + Q : Proc(g)}$$

TNT Types: BSum

$$\frac{\Gamma_1 \vdash P : BProc, \Gamma_2 \vdash Q : BProc, \Gamma_1 \# \Gamma_2}{\Gamma_1 \cup \Gamma_2 \vdash P + Q : BProc}$$

TNT Types: FTO

$$\frac{\Gamma_1 \vdash P : Proc(g), \Gamma_2 \vdash Q : Proc(g), \Gamma_1 \# \Gamma_2, \Gamma_1 \cup \Gamma_2 \vdash \sigma : Clock}{\Gamma_1 \cup \Gamma_2 \vdash [P]\sigma(Q) : Proc(g)}$$

TNT Types: STO

$$\frac{\Gamma_1 \vdash P : Proc(g), \Gamma_2 \vdash Q : Proc(g), \Gamma_1 \# \Gamma_2, \Gamma_1 \cup \Gamma_2 \vdash \sigma : Clock}{\Gamma_1 \cup \Gamma_2 \vdash [P]\sigma(Q) : Proc(g)}$$

TNT Types: Par

$$\frac{\Gamma_1 \vdash P : Proc(g), \Gamma_2 \vdash Q : Proc(g), \Gamma_1 \# \Gamma_2}{\Gamma_1 \cup \Gamma_2 \vdash P \mid Q : Proc(g)}$$

TNT Types: Rec

$$\frac{\Gamma \vdash P : Proc(g)}{\Gamma \vdash \mu X.P : Proc(g)}$$

TNT Types: BRec

$$\frac{\Gamma \vdash P : BProc}{\Gamma \vdash \mu X.P : BProc}$$

TNT Types: Res

$$\frac{\Gamma \vdash a : Act, \Gamma \vdash P : Proc(g)}{\Gamma \vdash P \setminus a : Proc(g)}$$

TNT Types: Amb

$$\frac{\Gamma \vdash m : \text{Amb}(g), \Gamma \vdash P : \text{Proc}(g), \Gamma \vdash B : \text{BProc}, \{\Gamma \vdash \sigma : \text{Clock} \mid \sigma \in \vec{\sigma}\}, \Gamma \vdash g : G, g' \in \mathcal{S}(G)}{\Gamma \vdash m[P]_{\vec{\sigma}}^B : \text{Amb}(g')}$$

TNT Types: Cap

$$\frac{\Gamma \vdash \mathcal{M} : Proc(g_1) \rightarrow Proc(g_2), \Gamma \vdash P : Proc(g_1)}{\Gamma \vdash \mathcal{M}.P : Proc(g_2)}$$

TNT Types: AmbIn

$$\frac{\Gamma \vdash g_2 : G_2, \Gamma \vdash m : \text{Amb}(g_1), g_1 \in \mathcal{C}(G_2)}{\Gamma \vdash \text{in } m \uparrow : \text{Proc}(g_2) \rightarrow \text{Proc}(g_2)}$$

TNT Types: AmbOut

$$\frac{\Gamma \vdash g_1 : G_1, \Gamma \vdash g_2 : G_2, \Gamma \vdash m : \text{Amb}(g_1), g_1 \in \mathcal{C}(G_2), \mathcal{S}(G_1) \subseteq \mathcal{S}(G_2)}{\Gamma \vdash \text{out } m \uparrow : \text{Proc}(g_2) \rightarrow \text{Proc}(g_2)}$$

TNT Types: Open

$$\frac{\Gamma \vdash g_1 : G_1, \Gamma \vdash g_2 : G_2, \Gamma \vdash m : \text{Amb}(g_1), g_1 \in \mathcal{O}(G_2), g_2 \in \mathcal{S}(G_1)}{\Gamma \vdash \text{open } m : \text{Proc}(g_2) \rightarrow \text{Proc}(g_2)}$$

TNT Types: BIn

$$\frac{}{\Gamma \vdash \overline{in} : BProc}$$

TNT Types: BOut

$$\frac{}{\Gamma \vdash \overline{out} : BProc}$$

TNT Types: BOpen

$$\frac{}{\Gamma \vdash \overline{open} : BProc}$$

The End

Thanks for listening.