香港中文大學
The Chinese University of Hong Kong

Tencent AI Lab

Interconnected Question Generation with Coreference Alignment and Conversation Flow Modeling

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Question Generation: Background

Question Generation: Related Work

- Dialogue
  - Seeking Information in Task-oriented Chatbot
  - Asking Clarification Questions (Rao and Daume, 2018)
  - Interactiveness and Persistance (Wang et al, 2018)

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Our Focus

Question Generation: Previous Setting

Incumbent Democratic President Bill Clinton was ineligible to serve a third term due to term limitations in the 22nd Amendment of the Constitution, and Vice President Gore was able to secure the Democratic nomination with relative ease.

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A: Democratic
Q: What was Clinton ineligible to serve?
A: third term
Q: Why was he ineligible to serve a third term?
A: term limitations

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Democratic nomination with relative ease.

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Machines?

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Question Generation + Conversation

Conversation is the ultimate way for human-machine interactions

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Question Generation + Conversation

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Standalone Interaction	**Conversational Questions**
Q: What political party is Clinton a member of?	Q1: What political party is Clinton a member of?
A: Democratic	A1: Democratic
Q: What was Clinton ineligible to serve? →	Q2: What was **he** ineligible to serve?
A: third term	A2: third term
Q: Why was he ineligible to serve a third term? →	Q3: **Why**?
A: term limitations	A3: term limitations

Conversational Question Generation

- Our Goal
  - A system needs to ask a series of **interconnected** questions grounded in a passage through a question-answering style conversation
  - Every question after the first turn might be dependent on the conversation history.

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A3: term limitations

Challenges

1. Generate **conversational interconnected** questions depending on the conversation so far

Q1: What political party is Clinton a member of?
A1: Democratic
Q2: What was **he** ineligible to serve?
A2: third term
Q3: Why?
A3: term limitations

Refer back to the conversation history using coreference

Challenges

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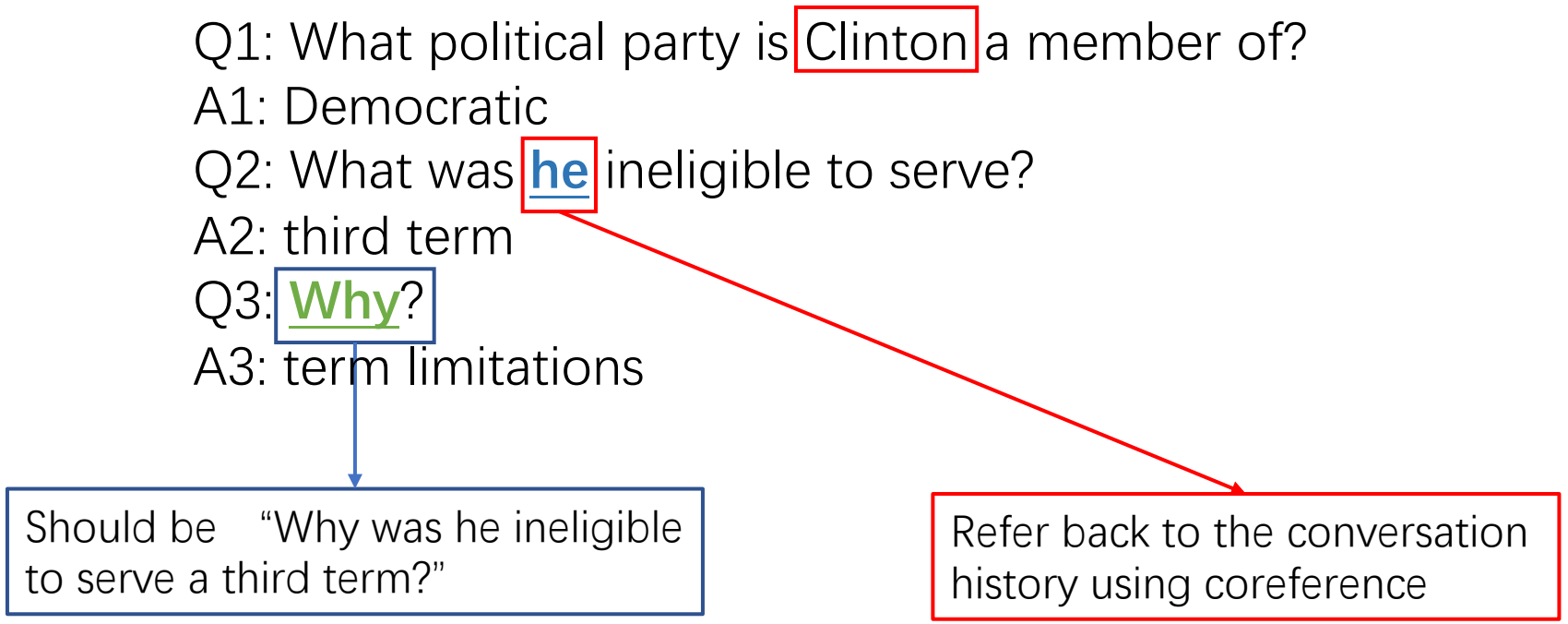

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2. A coherent conversation must have **smooth transitions** between turns
   - We expect the narrative structure of passages can influence the conversation flow of our interconnected questions

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Q1

Conversation Flow

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Q1
Q2
Q3

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Q1
Q2
Q3
Q4
…
Qn

Conversation Flow

Conversational Question Generation

- Challenges
  1. Generate **conversational interconnected** questions depending on the conversation so far
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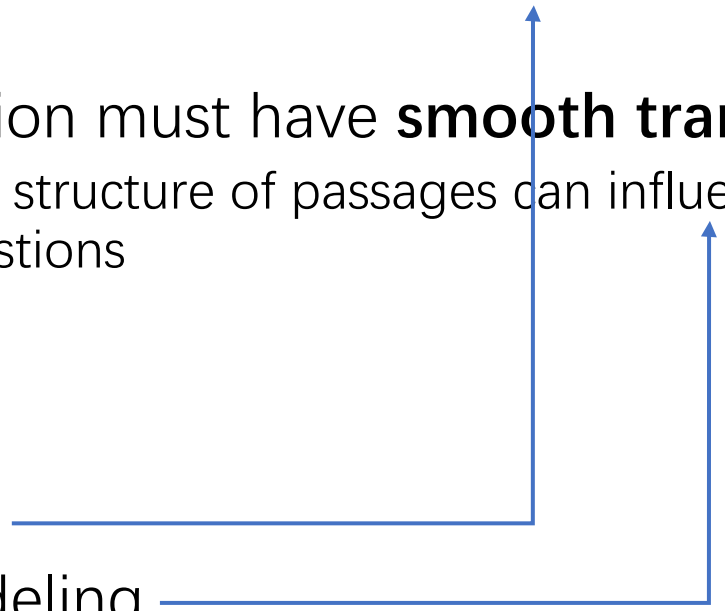
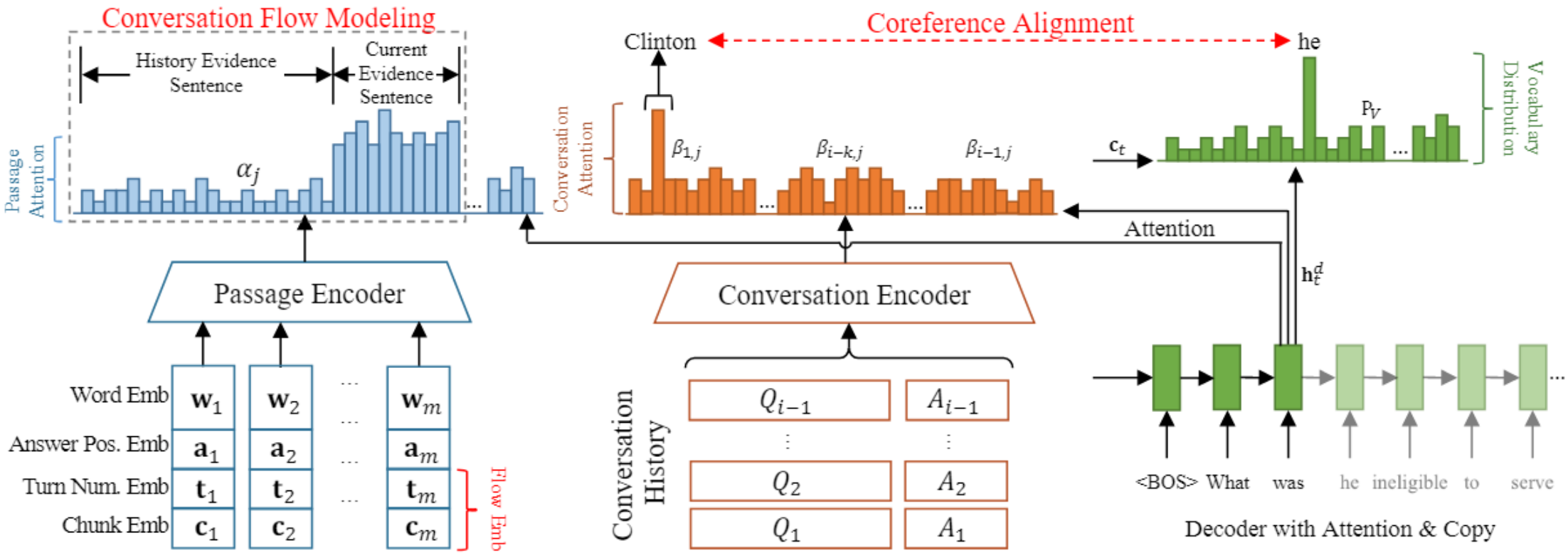
- Solutions
  - Coreference Alignment
  - Conversation Flow Modeling



Proposed Framework



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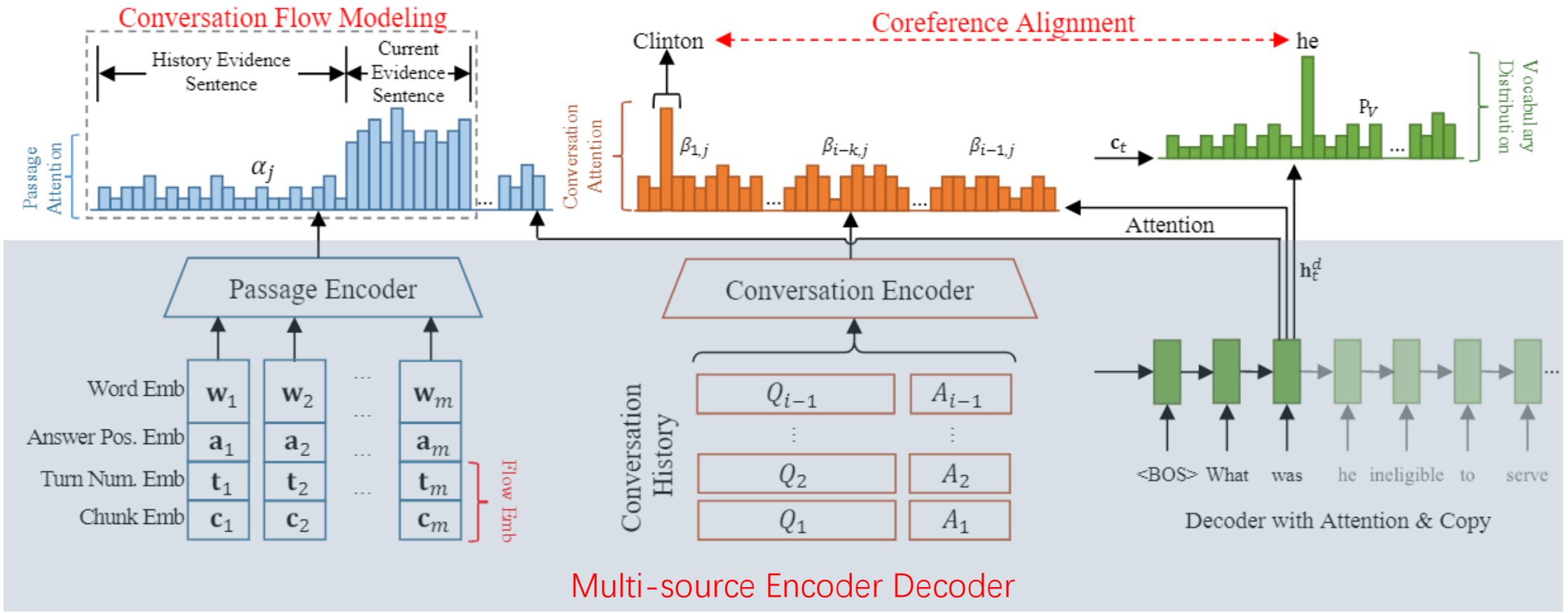

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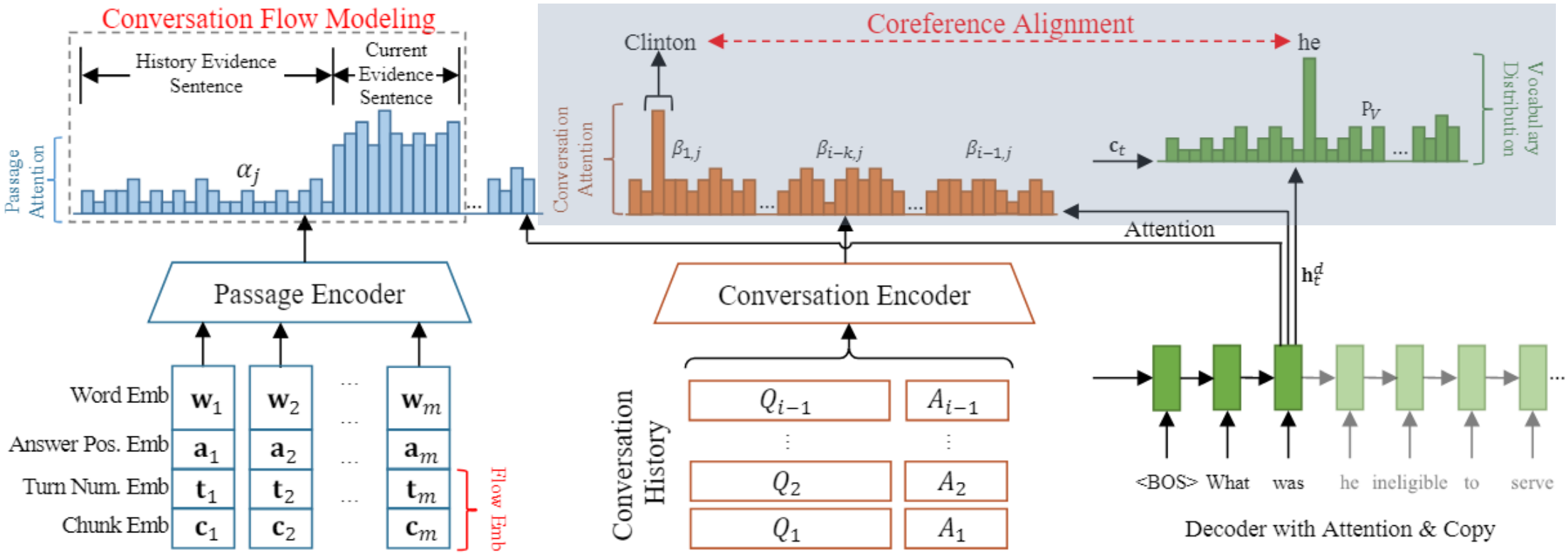

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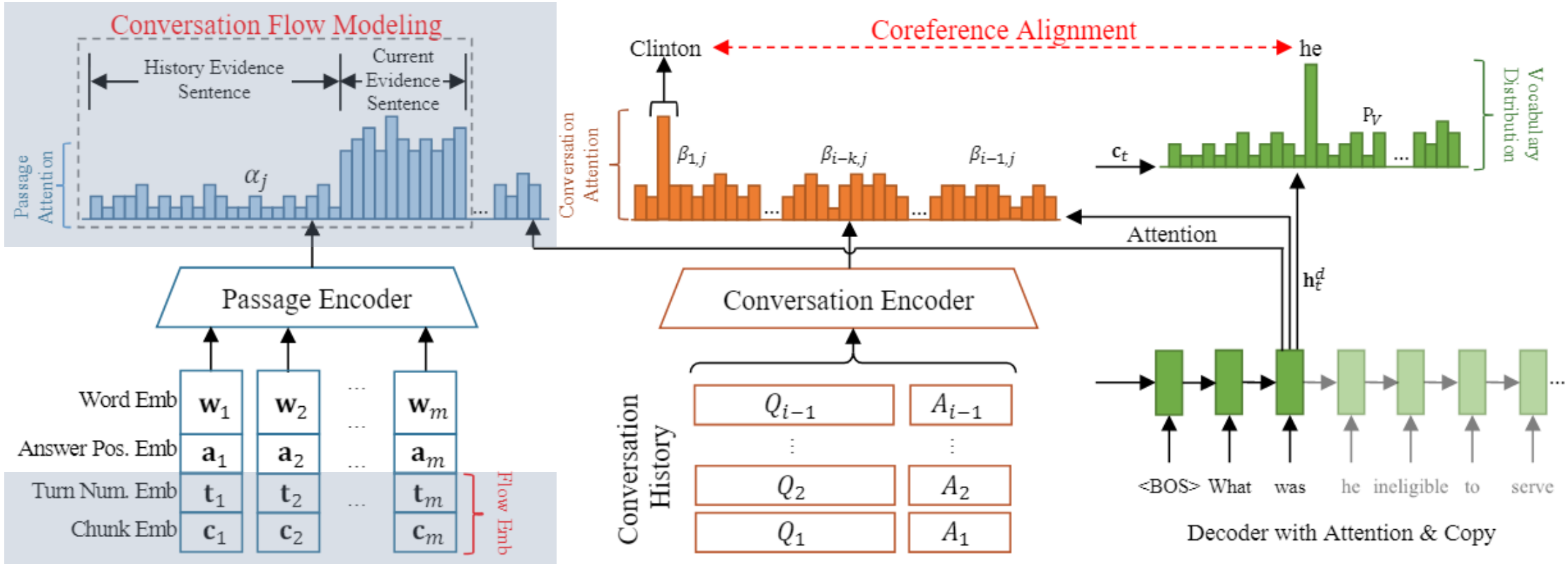
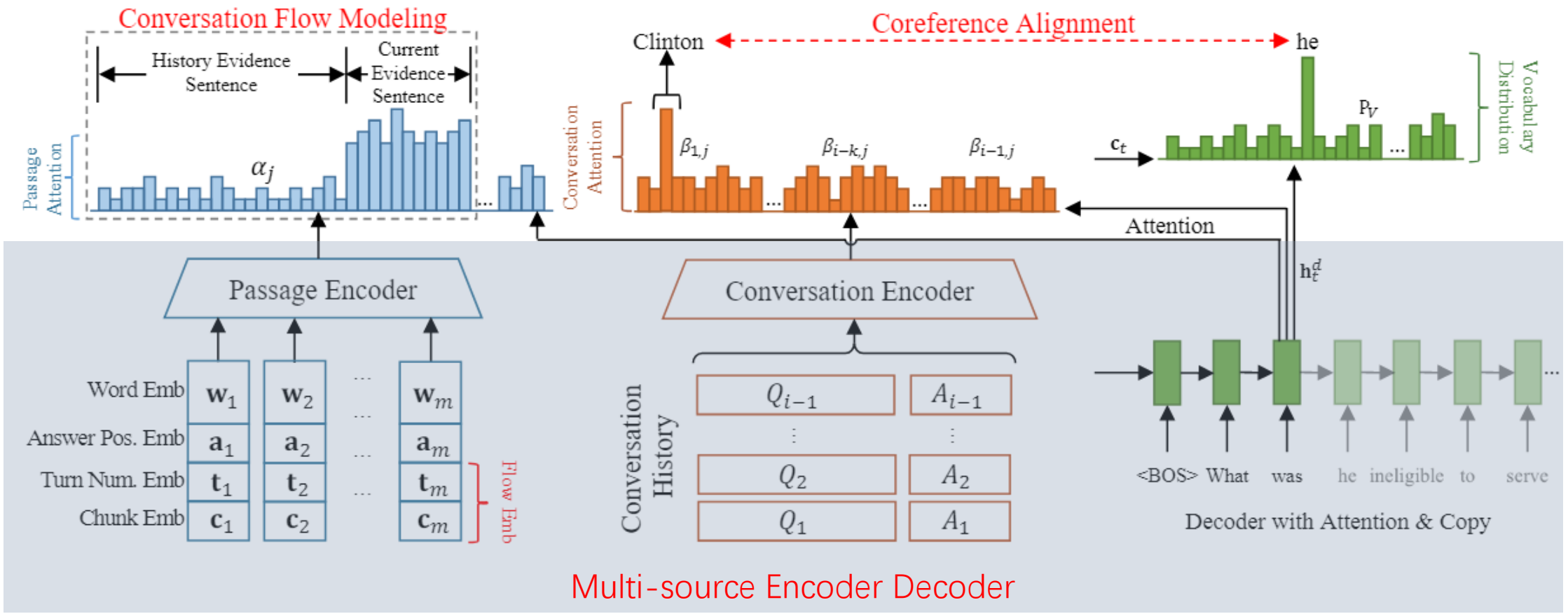
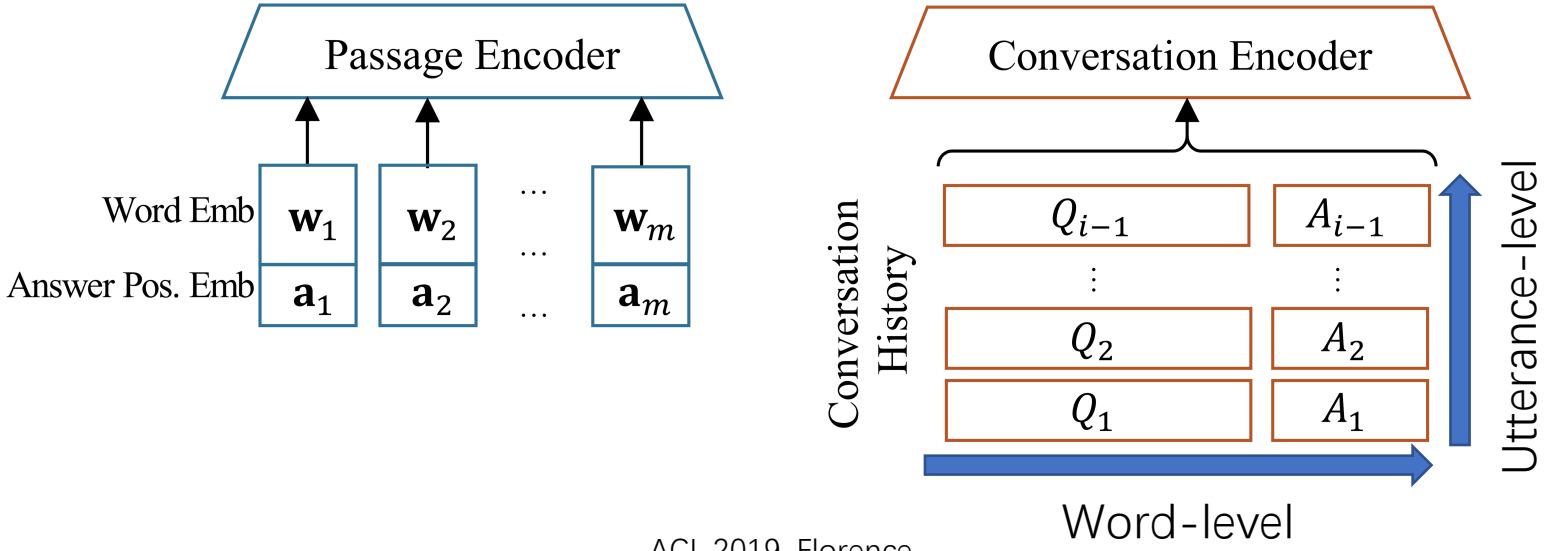


Multi-source Encoder Decoder



Multi-source Encoder Decoder

- Multi-source encoder jointly encodes the passage and conversation
  - Passage Representation: $(\mathbf{h}_1^p, \mathbf{h}_2^p, \ldots, \mathbf{h}_m^p)$
  - Conversation History Representation:
    - Word-level representation: $\left(\mathbf{h}_{i-k,1}^w, \ldots, \mathbf{h}_{i-k,m}^w\right)$, where $\mathrm{i} - k \in [1, i)$ is the turn number.
    - Utterance-level representation: $(\mathbf{h}_1^c, \ldots, \mathbf{h}_{i-1}^c)$



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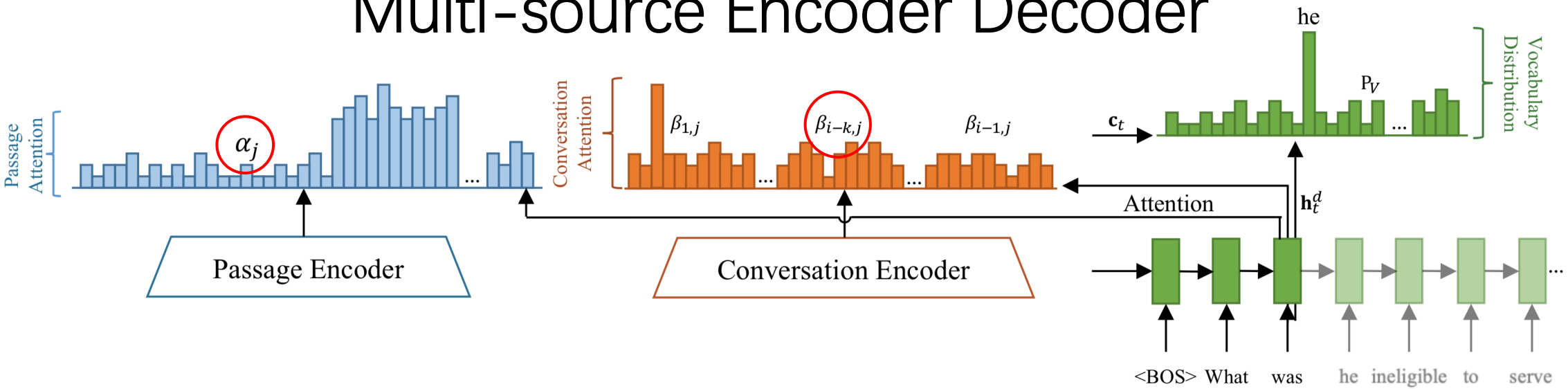
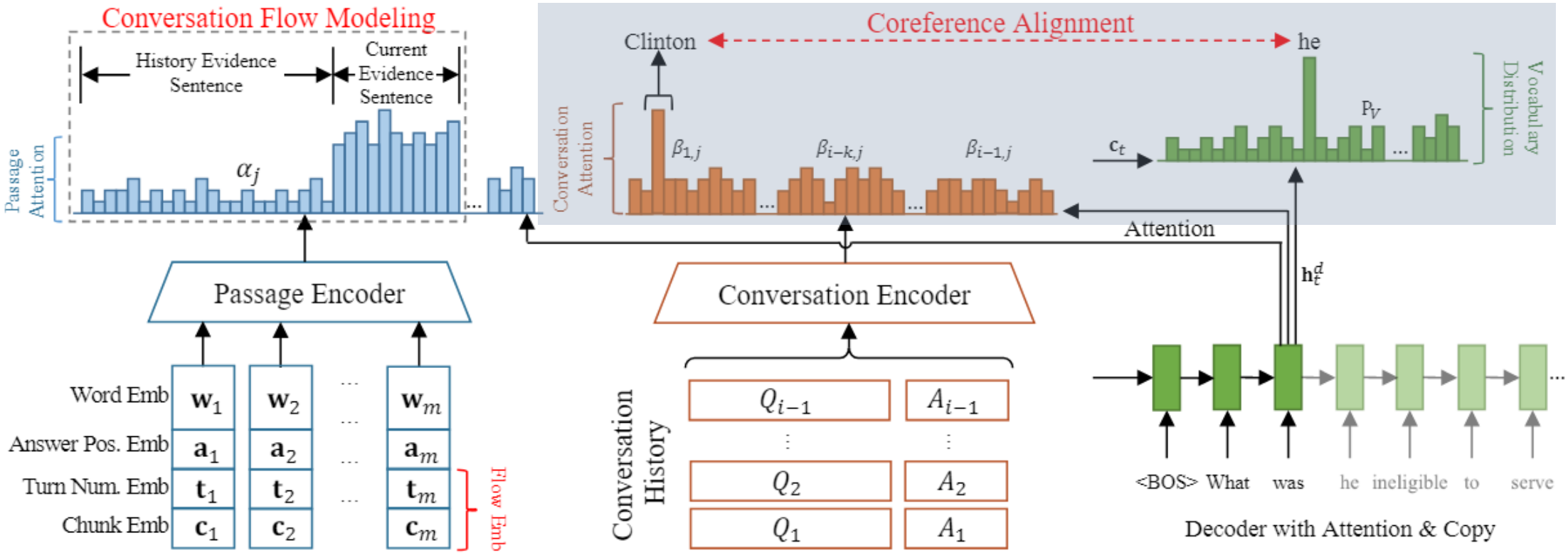


- The decoder itself decides to focus more on passage or conversation history:
  - Passage: $\mathbf{h}_j^p$, Conversation: $\mathbf{h}_{i-k,j}^w$, Decoder: $\mathbf{h}_t^d$
  - Use attention to calculate the importance score for each token in the passage and the conversation history as $\boldsymbol{\alpha_j}$ and $\boldsymbol{\beta_{i-k,j}}$ respectively;
  - Derive the context vector $\mathbf{c}_t$ and final vocabulary distribution P_V:

$$c_t = \Sigma_j \alpha_j \mathbf{h}_j^p + \Sigma_{k,j} \beta_{i-k,j} \mathbf{h}_{i-k,j}^w, \qquad P_V = \text{softmax}(\mathbf{W}_v \tanh(\mathbf{W}_a[\mathbf{h}_t^d; \mathbf{c}_t]))$$

Coreference Alignment

Generate conversational interconnected questions depending on the conversation so far



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Generate conversational interconnected questions depending on the conversation so far

- Explicitly **align** coreferent mentions in conversation history with corresponding pronominal references in generated questions
  - Preprocessing Stage

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What was he ineligible to serve?

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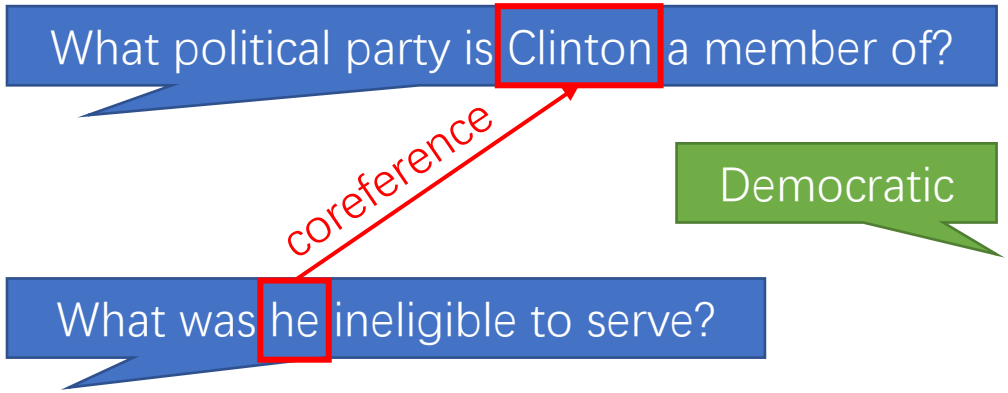

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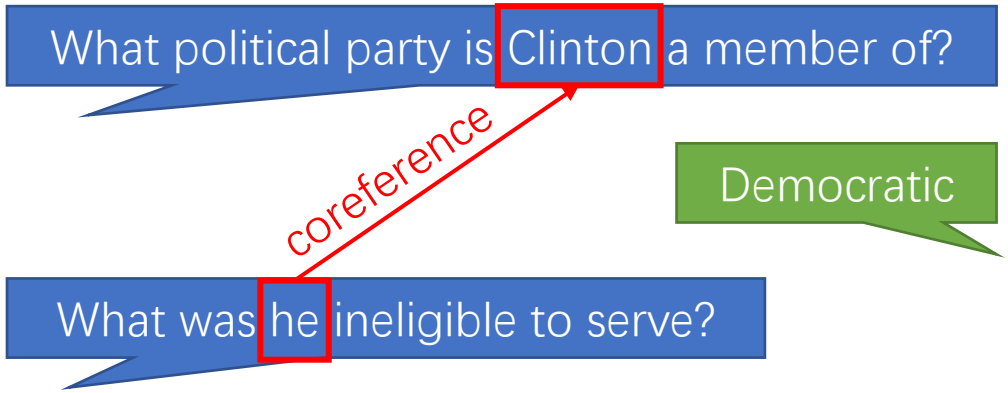
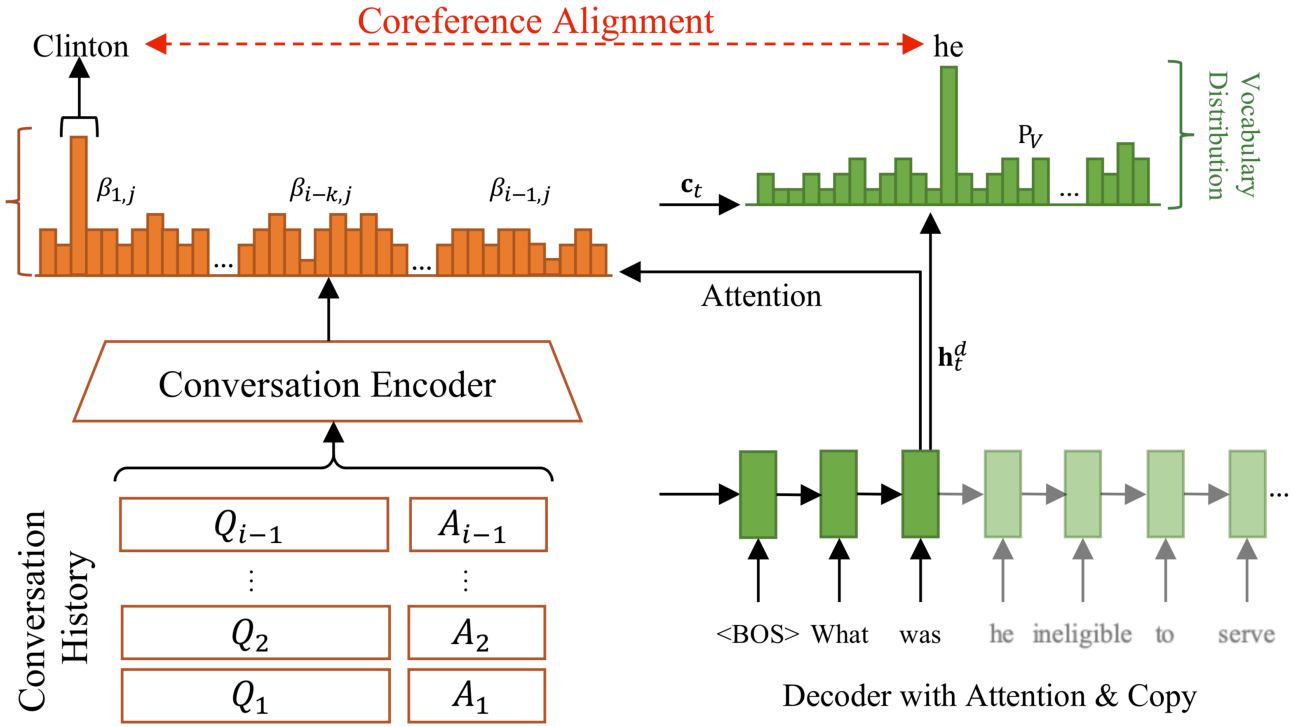


  - Training Stage

e.g., Clinton

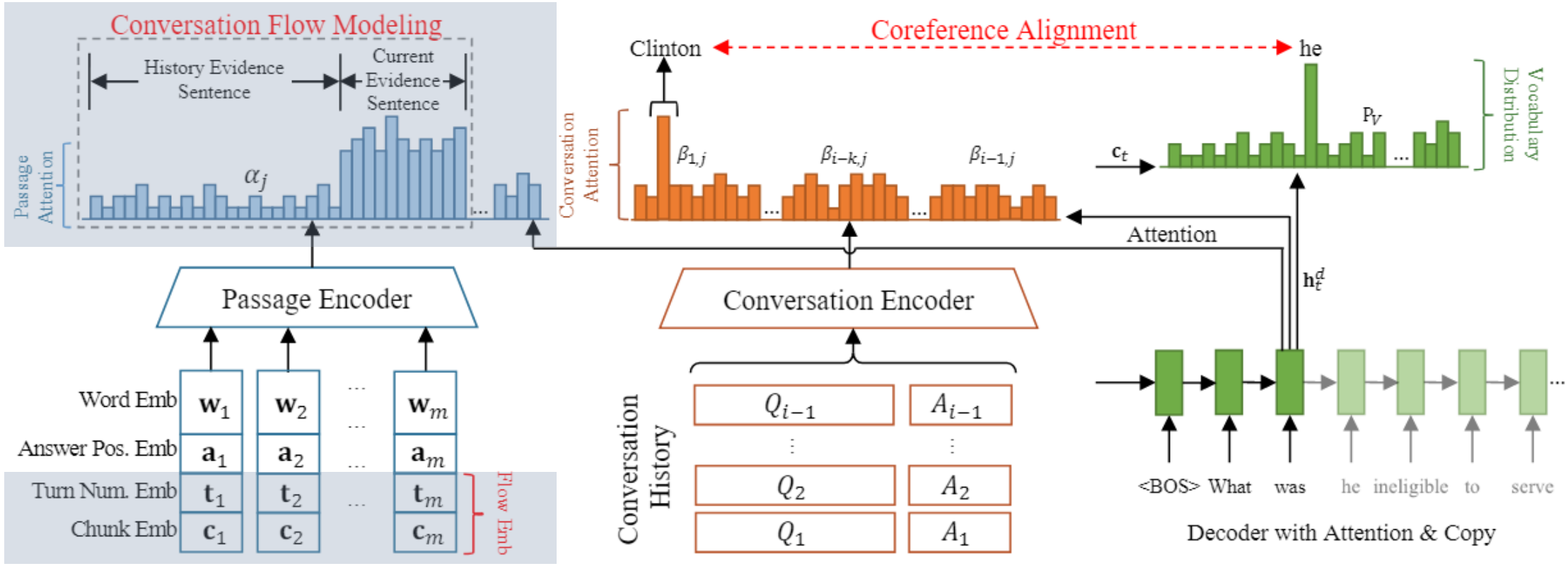
e.g., he

$$\mathcal{L}_{\text{coref}} = -(\lambda_1 \log \frac{\sum_j \beta_j^c}{\sum_{k,j} \beta_{i-k,j}} + \lambda_2 \log p_{\text{coref}}) * s_c$$



Conversation Flow Modeling

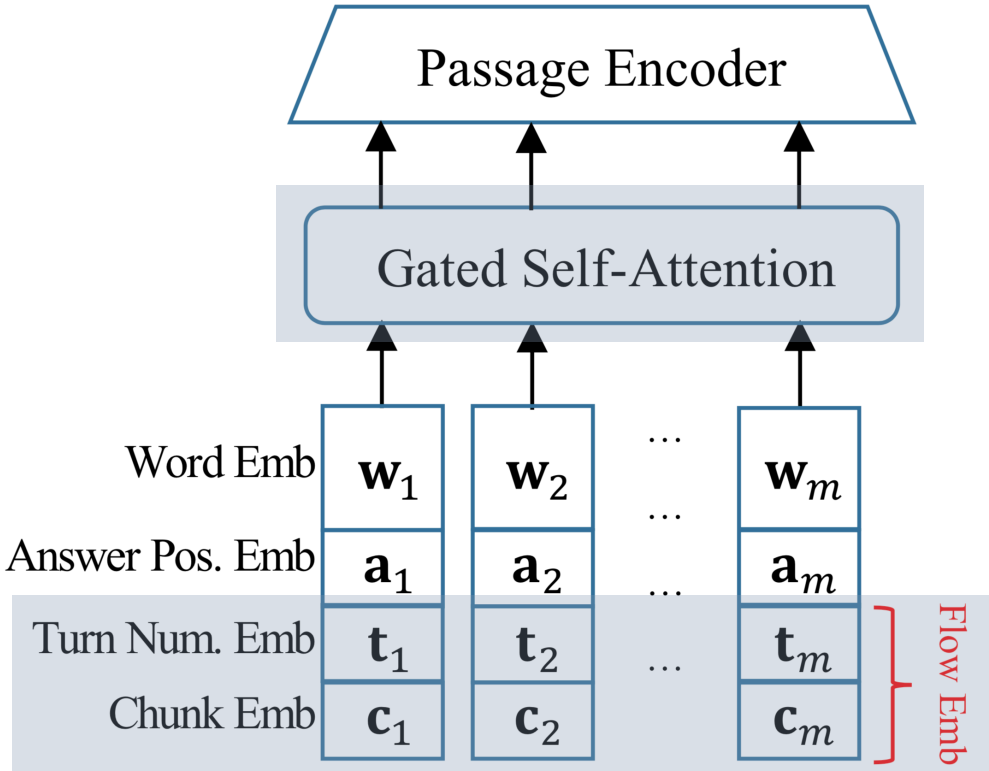
Model the conversation flow to transit focus inside the passage smoothly across turns



Conversation Flow Modeling: Flow Embedding

Convey the correlations between number of turns and narrative structure of passages

- Turn number embedding
  - Map the turn number into its feature embedding space
- Chunk embedding
  - Split the passage into L uniform chunks, and create an embedding vector for each chunk
- A gated self-attention mechanism over different embeddings
  - Learn the latent alignment between the turn number embedding and the chunk embedding



Conversation Flow Modeling: Flow Loss

1. Focus on sentences contain key information to generate the current turn question
2. Ignore sentences questioned several turns ago

Conversation Flow Modeling: Flow Loss

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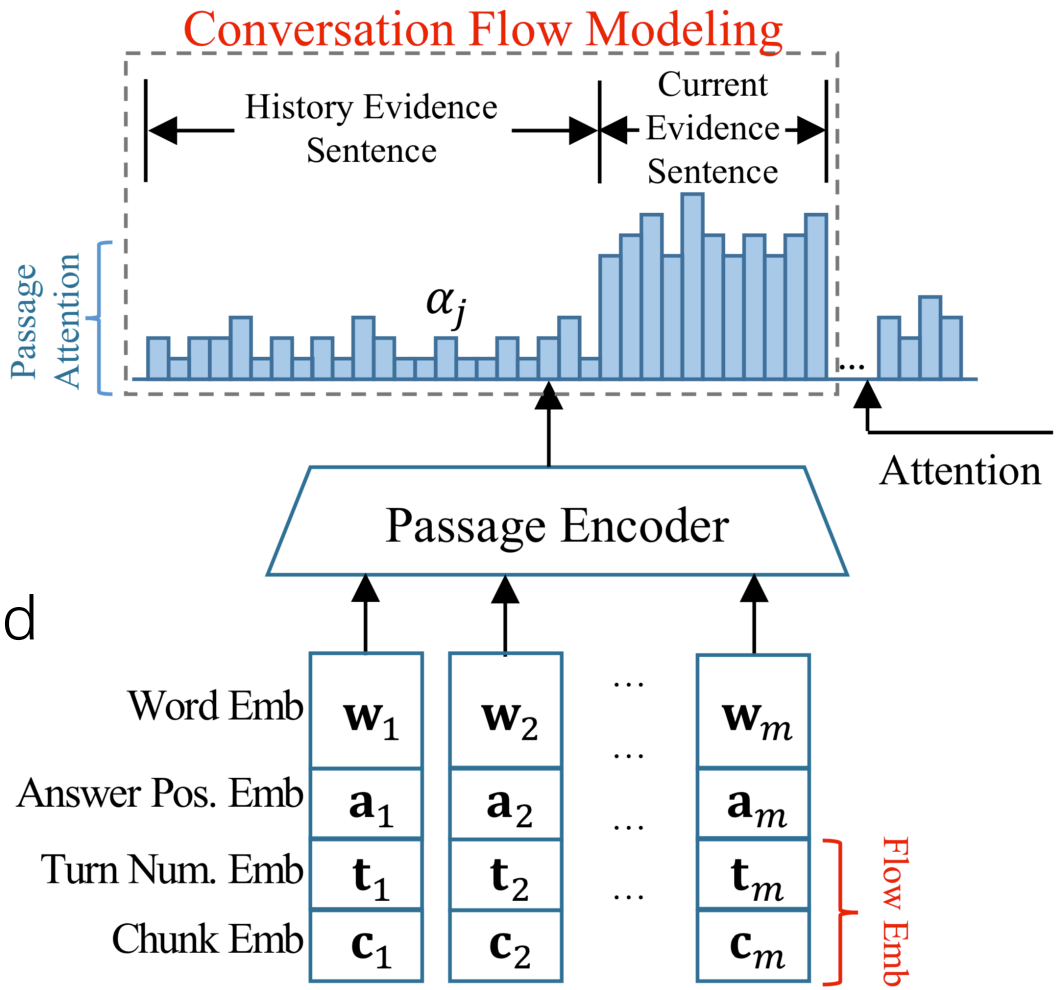
2. Ignore sentences questioned several turns ago History Evidence Sentence

Conversation Flow Modeling: Flow Loss

1. Focus on sentences contain key information to generate the current turn question — Current Evidence Sentence
2. Ignore sentences questioned several turns ago — History Evidence Sentence

- Focus on Current Evidence Sentence (CES): and ignore History Evidence Sentence (HES): via a flow loss:

$$\mathcal{L}_{\text{flow}} = -\lambda_3 \log \frac{\sum_{j:w_j \in \text{CES}} \alpha_j}{\sum_j \alpha_j} + \lambda_4 \frac{\sum_{j:w_j \in \text{HES}} \alpha_j}{\sum_j \alpha_j}$$



Dataset & Evaluation Metrics

- CoQA Dataset (Reddy et al., 2019)
  - A large-scale conversational question answering dataset
  - 8k conversations, 127k QA pairs
  - Short question length: 5.5 tokens (SQuAD: 10.1 tokens)
- Evaluation
  - Automatic Evaluation: BLEU, ROUGE
  - Human Evaluation

Main Results

- Baselines:
  - PGNet: Pointer-Generator Network
  - NQG: [Du and Cardie, 2018]
- Ablations:
  - MSNet: Multi-source EncDec
  - CorefNet: Coreference Alignment
  - FlowNet: Conversation Flow Modeling
  - CFNet: Our Full Model

	B1	B2	B3	R-L
PGNet	28.84*	13.74*	8.16*	39.18*
NQG	35.56*	21.14*	14.84*	45.58*
MSNet	36.27*	21.92*	15.51*	46.01*
CorefNet	36.89	22.28	15.77	46.53
FlowNet	36.87	22.49	15.98	46.64
CFNet	**37.38**	**22.81**	**16.25**	**46.90**

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Coreference Alignment Analysis

- Coreference Set
  - Each sample in the coreference set requires a pronoun resolution

Precision, Recall, F-score of pronouns in generated questions

	B1	B2	B3	R-L	P	R	F
PGNet	27.66*	13.82*	8.96*	38.40*	26.87*	25.17*	25.68*
NQG	34.75*	21.52*	15.96*	45.04*	34.46*	32.97*	33.25*
MSNet	36.31*	22.92	17.07	45.97*	35.34*	33.80*	34.07*
CorefNet	**37.51**	**24.14**	**18.44**	**47.45**	**42.09**	**40.35**	**40.64**

A large margin!

underline: p-value<0.05, *: p-value<0.01

Coreference Alignment Analysis

The attention probability when the model predicts a pronoun

Passage: … however , mccain has a very different life story . he grew up in a navy family and was a pilot during the vietnam war in the 1960s …

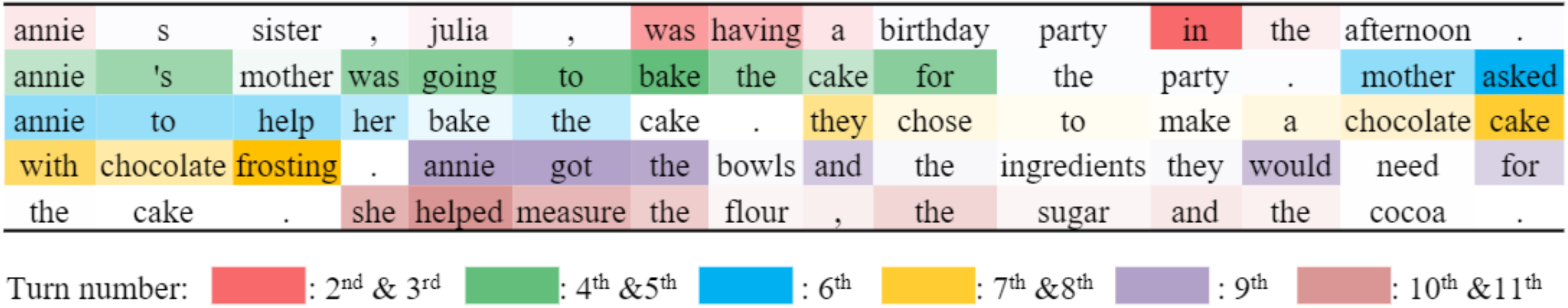
Conversation History:

<q>	what	war	was	mccain	in	?
0.0000	0.0001	0.0049	0.0138	0.7710	0.0055	0.0069
<a>	vietnam	war				
0.0000	0.0140	0.0095				
<q>	was	he	in	the	army	?
0.0000	0.0045	0.1303	0.0005	0.0139	0.0001	0.0250
<a>	no					
0.0000	0.0000					

Question (Human): what was his job ?

Question (Our Model): what was his job ?

Conversation Flow Analysis



The transition of passage attention distribution across turns

Human Evaluation

- We hire 5 annotators to rate 93 questions
- Rating criteria (1-3 scale, 3 for the best):
  - Grammaticality: the grammatical correctness and fluency
  - Answerability: whether the generated question can be answered by the current answer
  - **Interconnectedness**: whether the generated questions are *conversational* or not

	Grammaticality	Answerability	Interconnectedness
PGNet	2.74	1.39	1.59
MSNet	2.85	2.39	1.74
CFNet	2.89	**2.74***	**2.67***

*: p-value<0.01

Conclusion

- A new setting: Conversational Question Generation
- Coreference Alignment
- Conversation Flow Modeling

- Limitations and Future Work
  - Incorporate answer span identification into the current system
  - The answerer may also want to ask clarification questions
  - Domain adaptation (7 domains in CoQA dataset)
  - Gender Bias (his/he appears more frequently than her/she)

Reference

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Thanks

Code:

scan this

or https://github.com/Evan-Gao/conversational-QG